

**PALYNOLOGICAL INVESTIGATIONS RELATED TO
ARCHAEOLOGICAL SITES AND THE EXPANSION
OF WILD RICE (*Zizania aquatica* L.)
IN NORTHEAST MINNESOTA**

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ABSTRACT

Four pollen sequences, from Big Rice, Cloquet, Gegoka, and East Bearskin lakes in northeast Minnesota indicate that postglacial vegetation progressed from tundra to a shrub parkland or forest-tundra to a conifer-hardwood forest to a mixed conifer-hardwood forest and to an uppermost ragweed zone that indicates Euro-American settlement and deforestation beginning about 1890. Based on the abundance of Gramineae pollen in the Big Rice Lake pollen sequence, wild rice (*Zizania aquatica*) is present in harvestable quantities approximately 1,600 years before its known use in a Laurel occupation at the Big Rice archaeological site.

Pollen data from the uppermost sediment of Shannon Lake suggest that Gramineae abundance data may not indicate the presence of substantial wild rice beds in bays and shallows of lakes with large areas of deep open water. The Gramineae pollen profile from Gegoka Lake, which now supports wild rice over most of its surface, indicates that the current presence of wild rice in some lakes may be a relatively recent event.

Nonsiliceous algae recovered in conjunction with pollen from Big Rice, Cloquet, Gegoka, and East Bearskin lakes indicate that each lake has undergone cycles of nutrient enrichment. Changing environmental or limnologic competition, or both, as well as competition by macrophytic vegetation, is indicated by oscillations in nonsiliceous algae abundance.

Gramineae abundance data and Gramineae pollen grain size distribution data indicate that wild rice was probably present in harvestable quantities in northeast Minnesota in late Paleoindian times and has persisted up to the present. Gramineae

pollen grain size distribution data was especially useful in identifying the probable presence of prehistoric wild rice in lakes that have Gramineae pollen profiles with low to moderate abundances. The advantages of using both palynological methods to determine prehistoric wild rice lakes is demonstrated by the Wild Rice Lake Reservoir pollen sequence.

Preliminary data indicate a much greater association of Woodland sites and historic wild rice lakes than of Paleoindian/Archaic sites and wild rice lakes. This suggests that wild rice became a more important food resource in the Woodland Period.

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*Never give up on
Your Dreams,
They always come true
with dedication.*

Bill Huber

I. INTRODUCTION

Vegetational change has played an integral role in the changing patterns of prehistoric subsistence and settlement. Beginning with the Paleoindian period in northeast Minnesota, prehistoric peoples have depended directly or indirectly on the available vegetational resources in the area. The availability of plant resources for faunal and human consumption allowed the settlement of newly opened lands after deglaciation. Subsequent changes in the climate and vegetation have played a crucial role in prehistoric peoples' adaptation of subsistence strategies to their environment.

Palynology, the study of pollen and spores and their dispersal, has for many years been a primary tool for paleoecologists. Palynological data from bogs, marshes, and lakes are important in establishing past vegetational and climatic records (Kapp, 1969; Faegri and Iverson, 1975; Moore and Webb, 1978). Subsequently, archaeologists have realized the importance of palynological investigations as part of multidisciplinary archaeological studies (Dimbleby, 1985; King, 1985; Rapp and Hill, 1998). The correlation of stratigraphically continuous pollen data with archaeological sites in the same area may yield valuable information for paleoenvironmental reconstruction of a site (King, 1985). Changes in both local and regional vegetation as well as climate may be very important in the interpretation of archaeological data (King, 1985). Palynological data can also be used to identify cultigens and wild plants gathered for food or raw materials; to obtain dietary information; to study site seasonality (King, 1985); and to determine potential resource plants (King, 1976; Huber, 1987b). Pollen grains may yield the only evidence of cultigens or wild plants

gathered for food or raw materials at a site where soft plant tissues are rarely preserved (King, 1985). Therefore, palynological investigations of archaeological and traditional pollen-bearing sediments may yield valuable insights into the relationship of humans to their environment (Huber, 1987b; Dimbleby, 1985; King, 1985).

Of interest to a great many archaeologists who study subsistence patterns in northeast Minnesota is the availability of wild rice (*Zizania aquatica*). It has long been thought that wild rice has had a major influence on the prehistoric peoples and cultural change in northeast Minnesota and the Upper Great Lakes region (Jenks, 1900; Densmore, 1928; Stoltman, 1973; Rajnovich, 1984; Anfinson, and Wright, 1990). The availability and abundance of wild rice in the past and the use of wild rice by and its influence on prehistoric people in northeast Minnesota (Johnson, 1969b; McAndrews, 1969, 1980; Gibbon and Cain, 1980) has led to much argument among archaeologists and paleoecologists, among the questions debated are: 1) When did wild rice become available in quantities large enough to subsidize the food base?, 2) Based on the abundance of Gramineae pollen, is it possible to determine the presence of wild rice in harvestable quantities in a lake?, and 3) Was pottery introduced to northeast Minnesota in order to process wild rice?

This thesis has seven fundamental objectives:

- Create a paleoenvironmental reconstruction based on palynological data that can serve as a context for component site sequences at the Big Rice, Cloquet Lake Boat Landing, Bearskin Point, and Misiano archaeological sites in the Arrowhead Region of northeast Minnesota.
- Provide a history of wild rice for northeast and greater Minnesota based on existing and new pollen data.
- Evaluate what constitutes a wild rice lake in the past and at present.
- Provide a means of determining the probable presence of wild rice in the paleoecological record of a lake based on pollen data.
- Evaluate the potential for the use of wild rice as a food source prior to the Woodland Period in northeast Minnesota based on pollen data.
- Based on historic and ethnographic data, determine if it is possible to extensively use wild rice without leaving a signature in the archaeological record.
- Based on currently available data, determine if there is a correlation between Woodland archaeological sites and historical wild rice lakes.

II. EVOLUTION OF THE NATURAL ENVIRONMENT

LATE WISCONSINAN GLACIAL HISTORY

During the Late Wisconsinan, glacial ice advanced into Minnesota from three general directions. The three ice lobes are the Red River Lobe, which includes the Des Moines Lobe, Koochiching Lobe, and the St. Louis Sublobe from the Red River Valley; the Rainy Lobe from the Canadian border; and the Superior Lobe from the Lake Superior basin (Wright, 1972). The glacial ice reached its maximum extent about 18,000 years ago (Teller, 1987).

Although much of Minnesota was covered by ice from the Des Moines, Rainy, and Superior lobes, an ice-free embayment existed in north-central Minnesota by 13,500 yr B.P. (Fig. 1). This open embayment was accessible from west-central Wisconsin (Mulholland and others, 1997). The open embayment had enlarged by 13,000 yr. B.P. (Fig. 2) by extending to the north and northeast, as well as to the south, as the Grantsburg Sublobe wasted (Mulholland and others, 1997) during the Split Rock phase (Wright, 1972). The Superior Lobe extended south out of the Superior Basin but did not cut off access to the open embayment from the east (Mulholland and others, 1997).

Most of central and southern Minnesota was ice-free by 12,800 yr B.P. (Fig. 3), with a precursor to Glacial Lake Duluth in the Superior basin (Mulholland and others, 1997). At about 12,500 yr B.P., during the Nickerson phase (Wright, 1972), the Superior Lobe readvanced and filled the Superior Basin, although it did not restrict access to the ice-free area from the east (Fig. 4). Except for the northern rim

of the Superior basin, most of northeast Minnesota became open as ice continued to waste away (Mulholland and others, 1997).

The St. Louis Sublobe of the Des Moines Lobe advanced to the southeast at approximately 12,200 yr B.P. In the process, it covered a large portion of north central Minnesota (Fig. 5). The Superior Lobe was still active at this time. However, most of northeastern Minnesota was probably ice-free with an open corridor to the south (Mulholland and others, 1997). By 11,800 yr B.P., most of the ice had retreated from northeast Minnesota (Teller, 1987). At this time Glacial Lake Duluth, Glacial Lake Aitkin II, and Glacial Lake Upham II (Fig. 6) were in existence (Mulholland and others, 1997). By 11,500, northeast Minnesota was virtually ice-free (Fig. 7). At the time it was bounded by Glacial Lake Agassiz on the west and Glacial Lake Duluth and the Superior Lobe on the east (Mulholland and others, 1997). Ice continued to retreat until approximately 10,000 yr B.P. when the Marquette readvance of the Superior occurred (Fig. 8). Ice may have extended as far west as the north shore of the Superior basin (Teller, 1987). However, some evidence indicates that the ice may not have extended this far west or may not have covered the area extensively (Mulholland and others, 1997). By 9,500 yr B.P., northeast Minnesota was ice-free (Mulholland and others, 1997) and Glacial Lake Minong occupied the Superior basin (Farrand and Drexler, 1985). For a more detailed review of the late glacial history of northeast Minnesota, see Mulholland and others (1997).

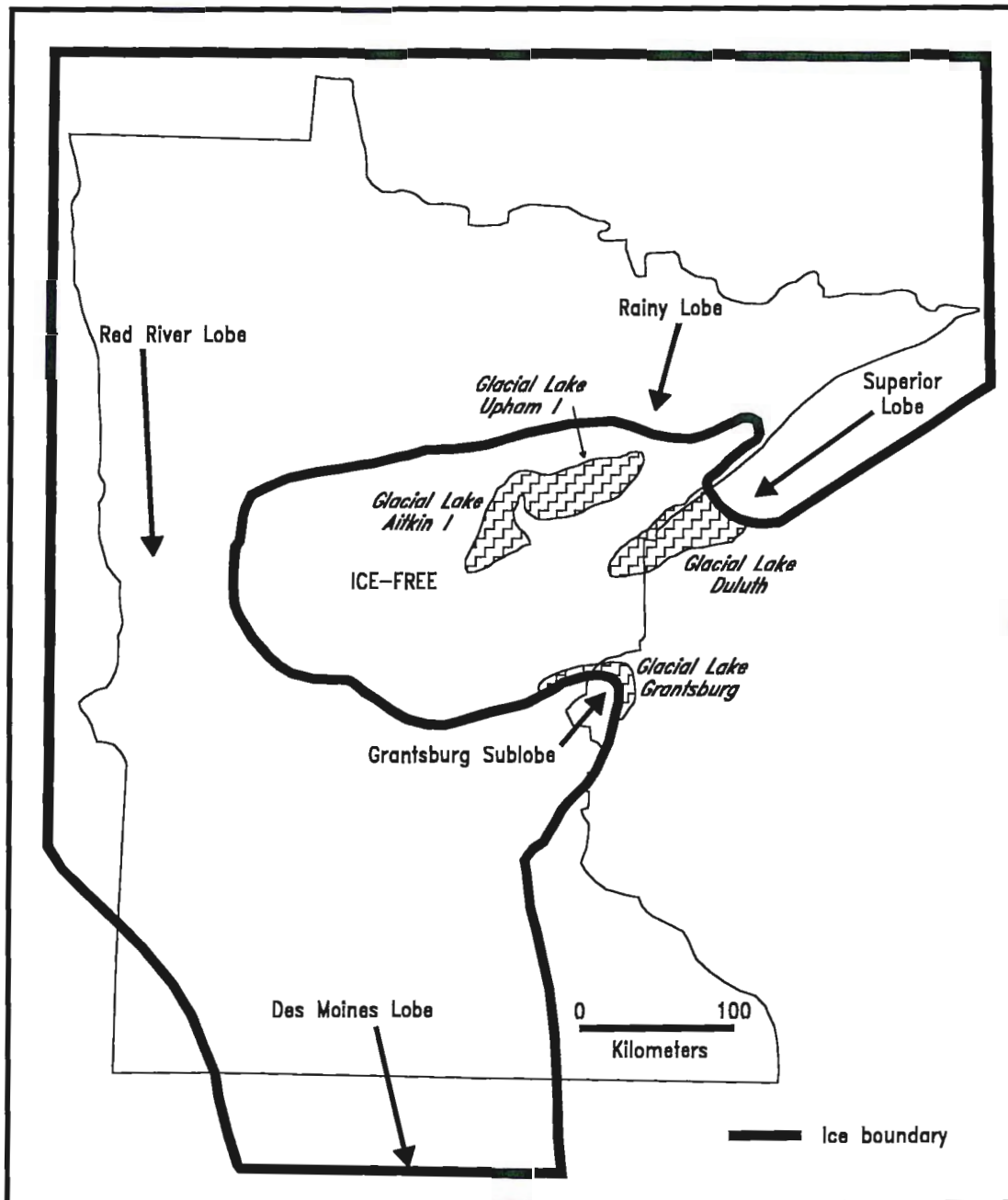


Figure 1. Glacial lobes and lakes at 13,500 B.P. (Modified from Mulholland and others, 1997).

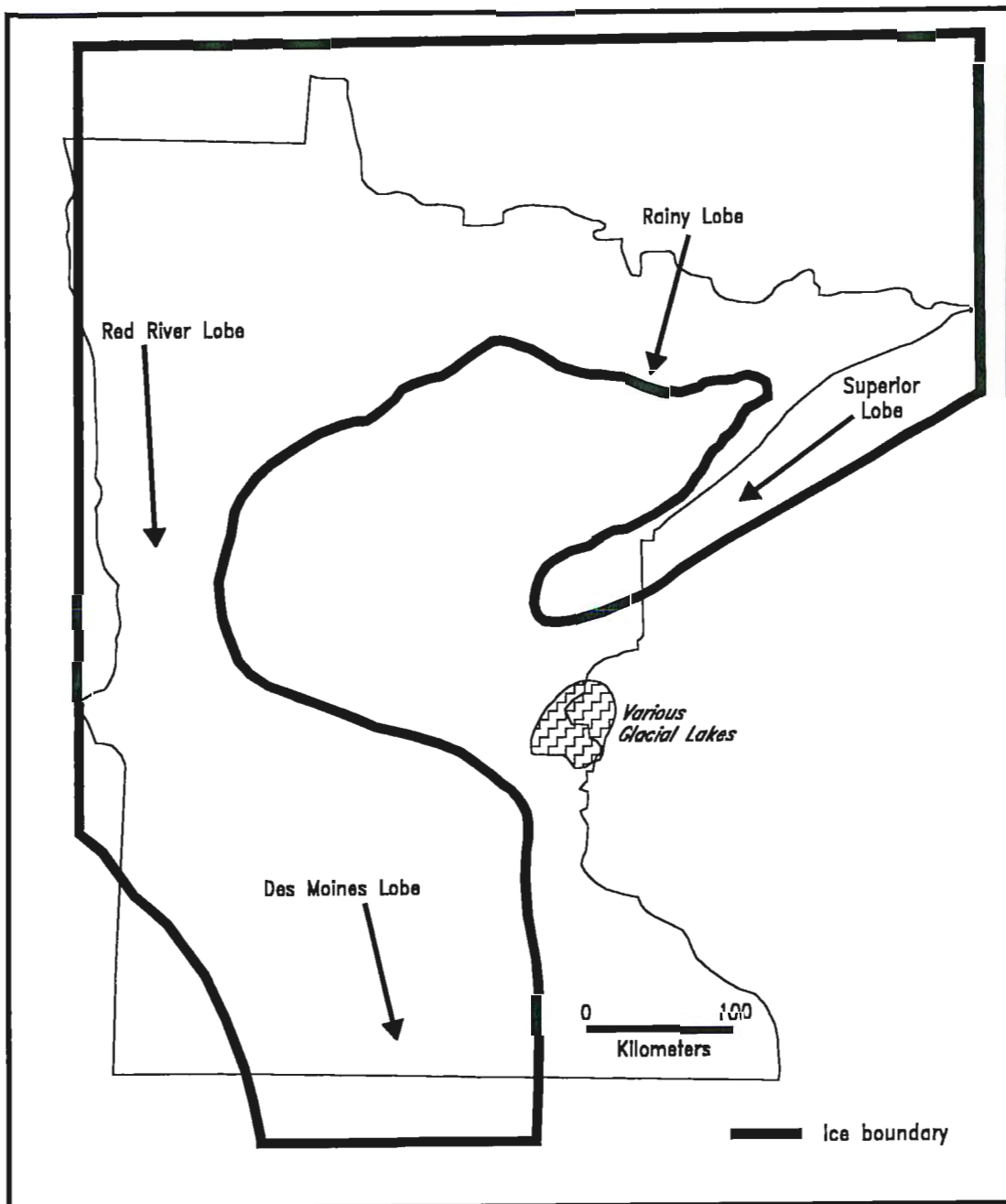


Figure 2. Glacial lobes and lakes at 13,000 B.P. (Modified from Mulholland and others, 1997).

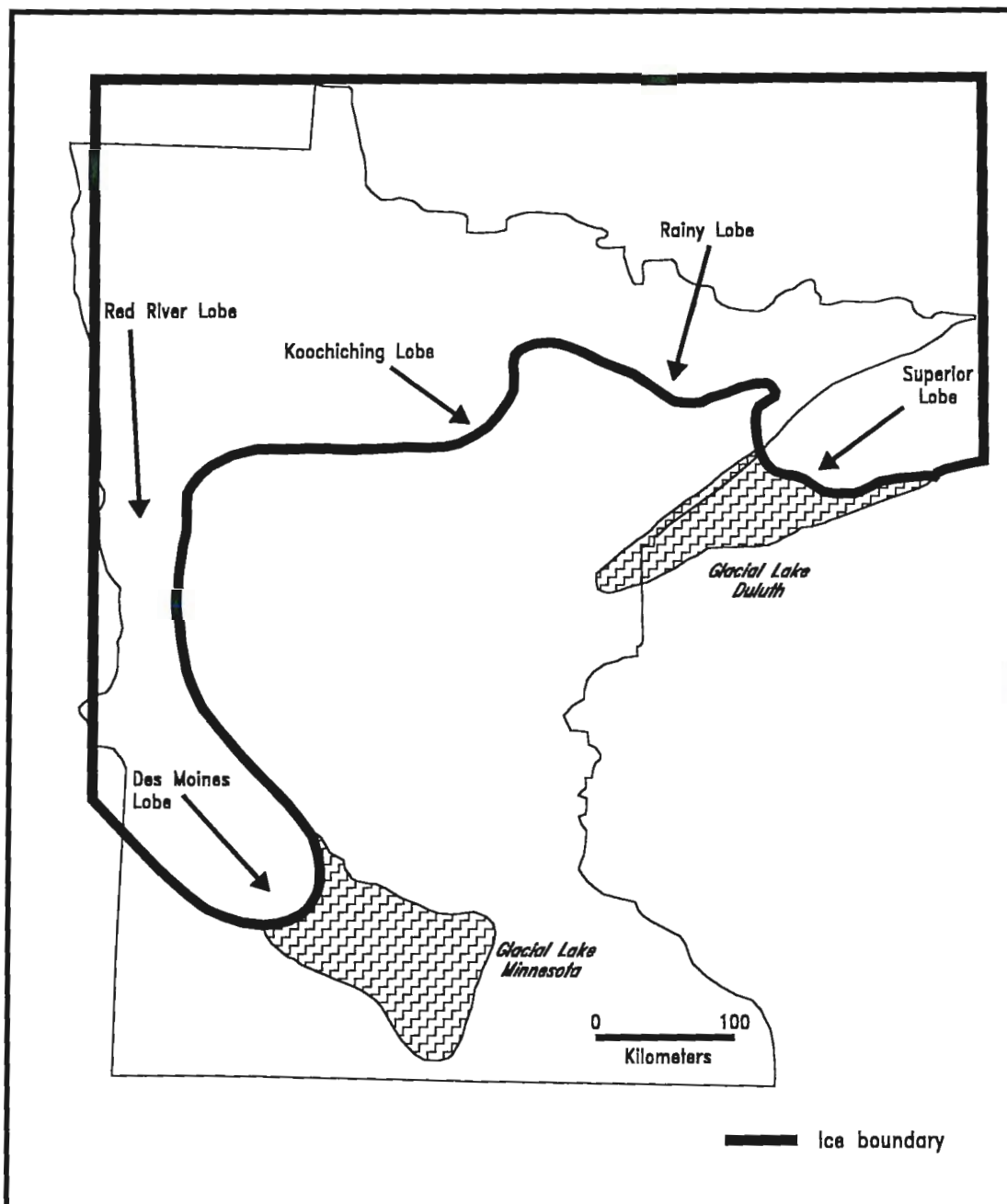


Figure 3. Glacial lobes and lakes at 12,800 B.P. (Modified from Mulholland and others, 1997).

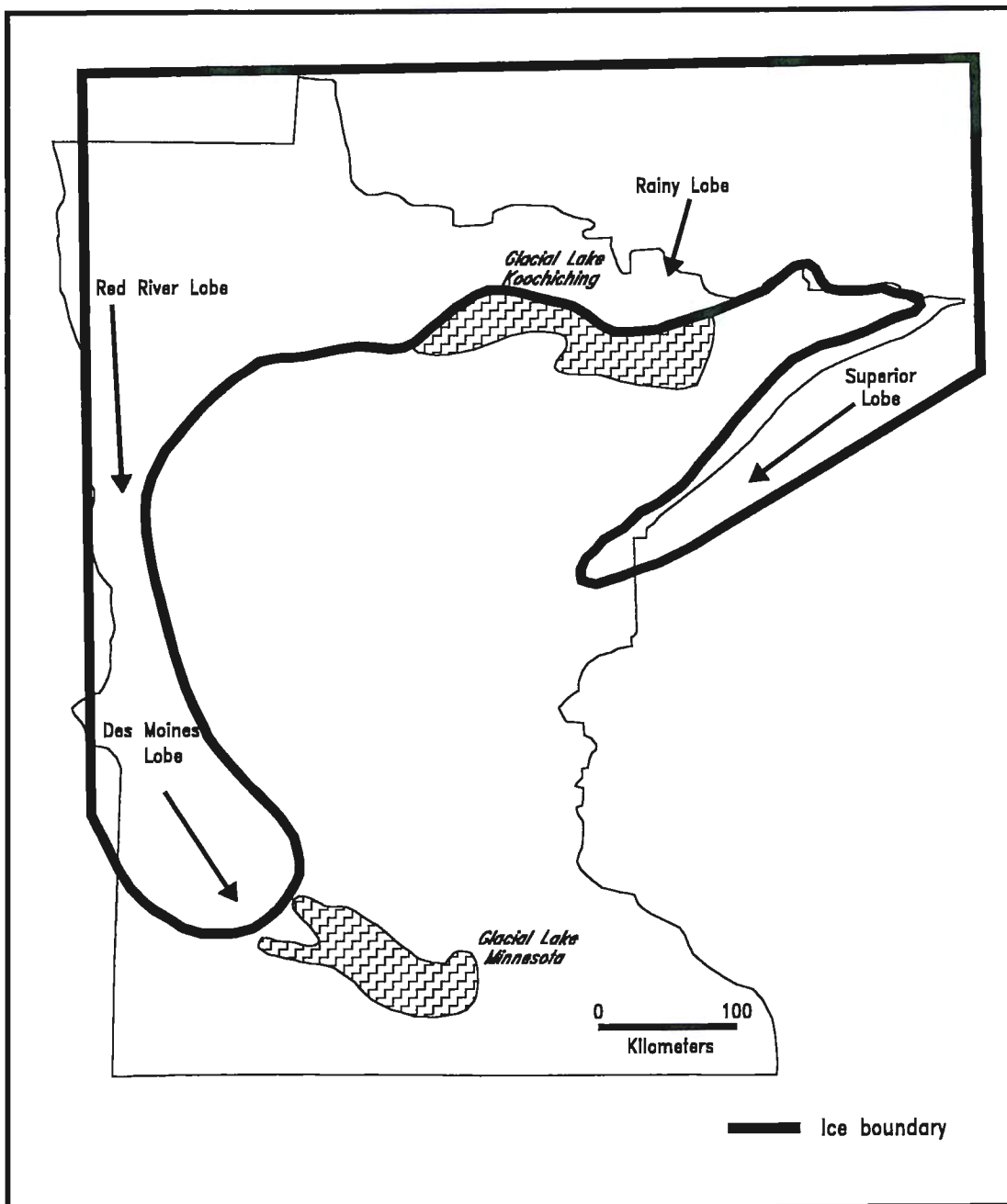


Figure 4. Glacial lobes and lakes at 12,500 B.P. (Modified from Mulholland and others, 1997).

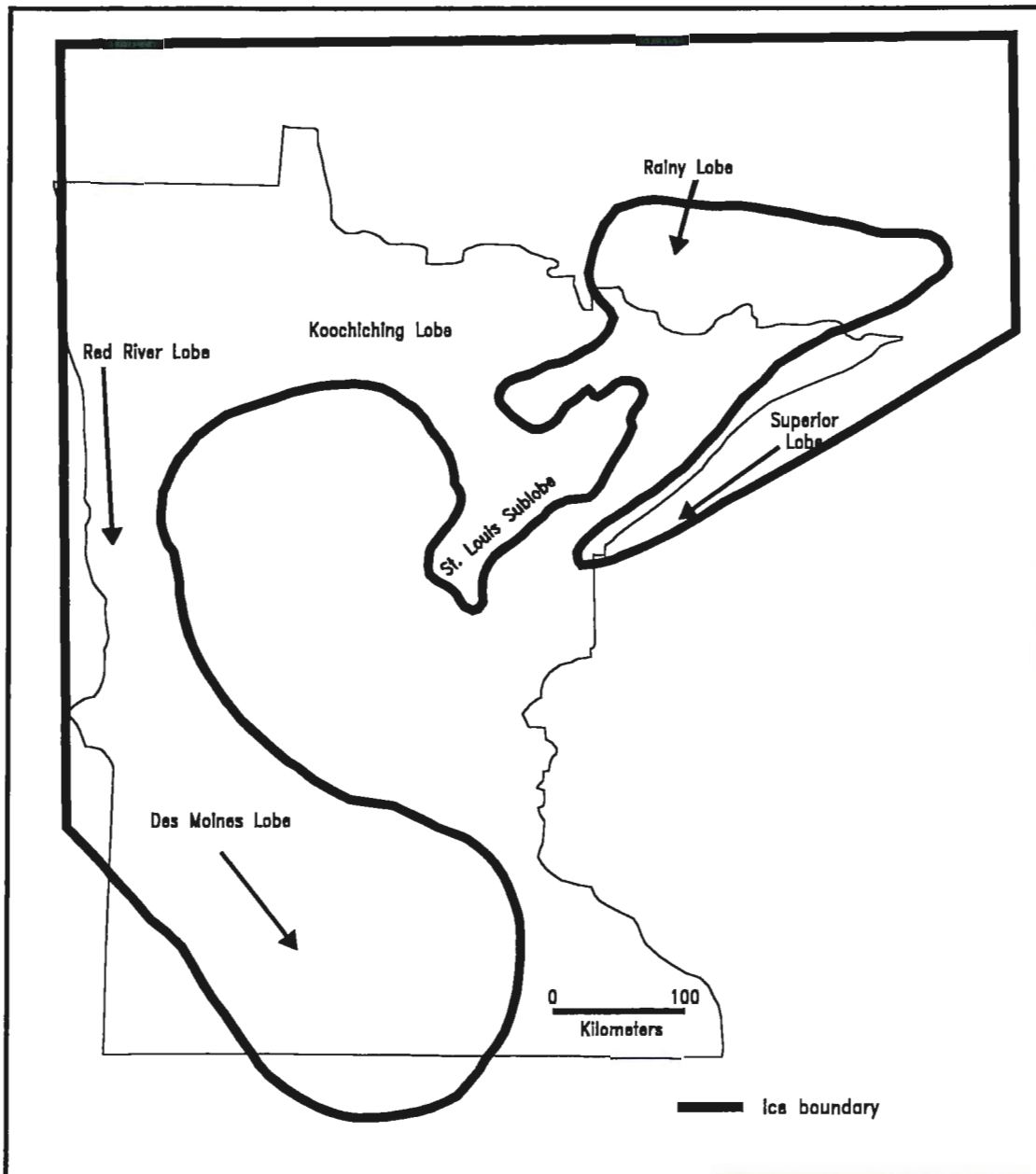


Figure 5. Glacial lobes and lakes at 12,200 B.P. (Modified from Mulholland and others, 1997).

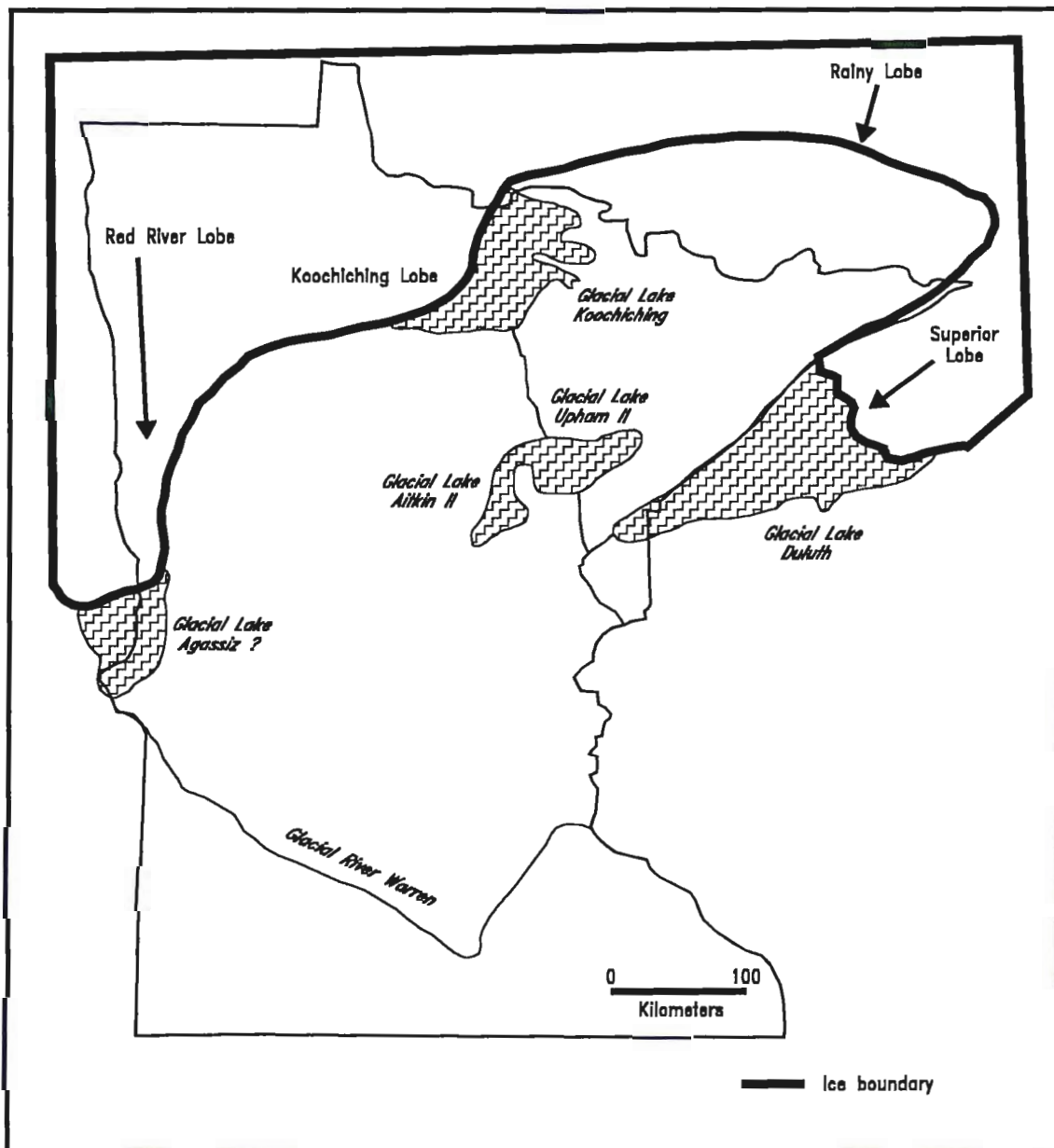


Figure 6. Glacial lobes and lakes at 11,800 B.P. (Modified from Mulholland and others, 1997).

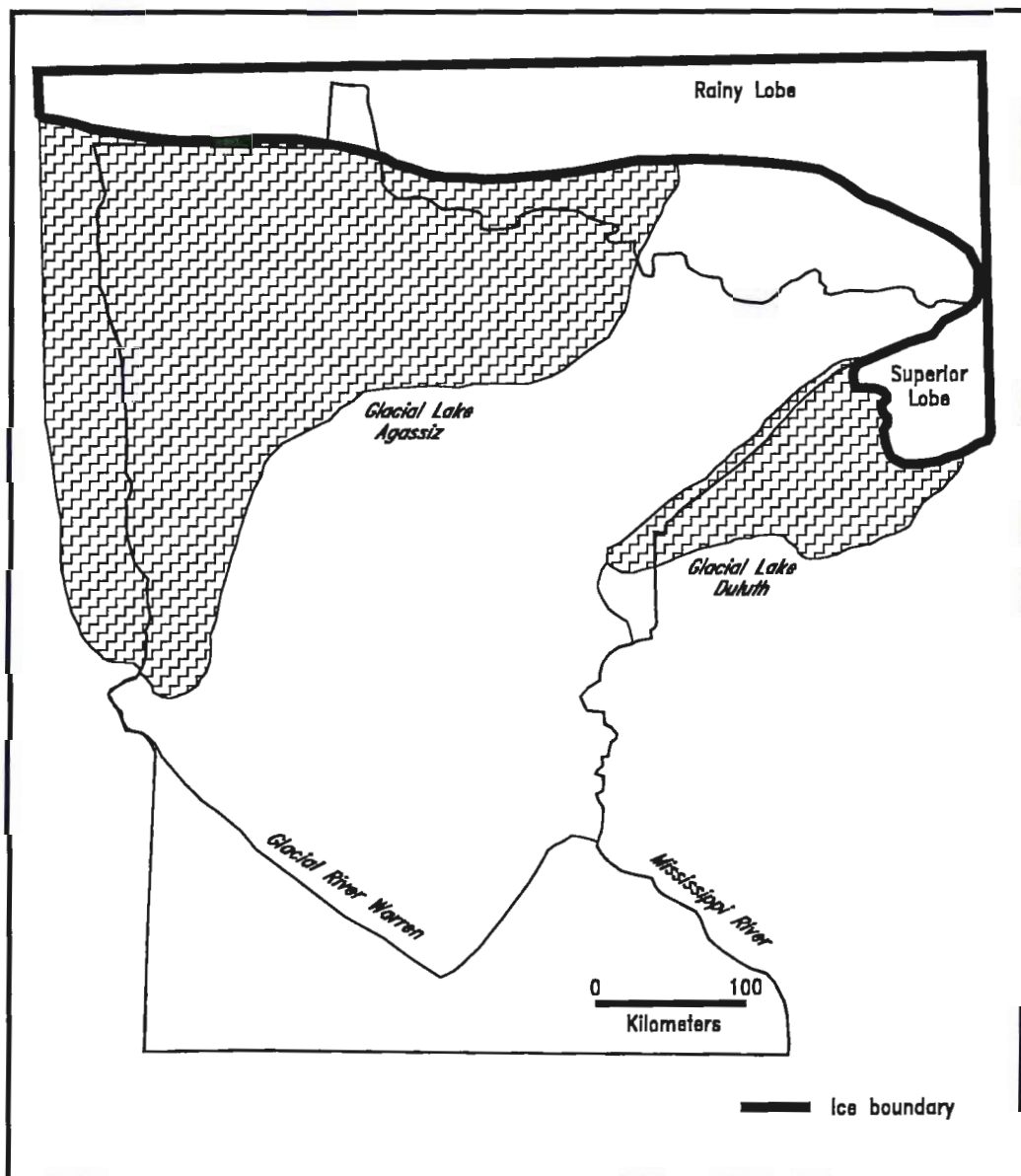


Figure 7. Glacial lobes and lakes at 11,500 B.P. (Modified from Mulholland and others, 1997).

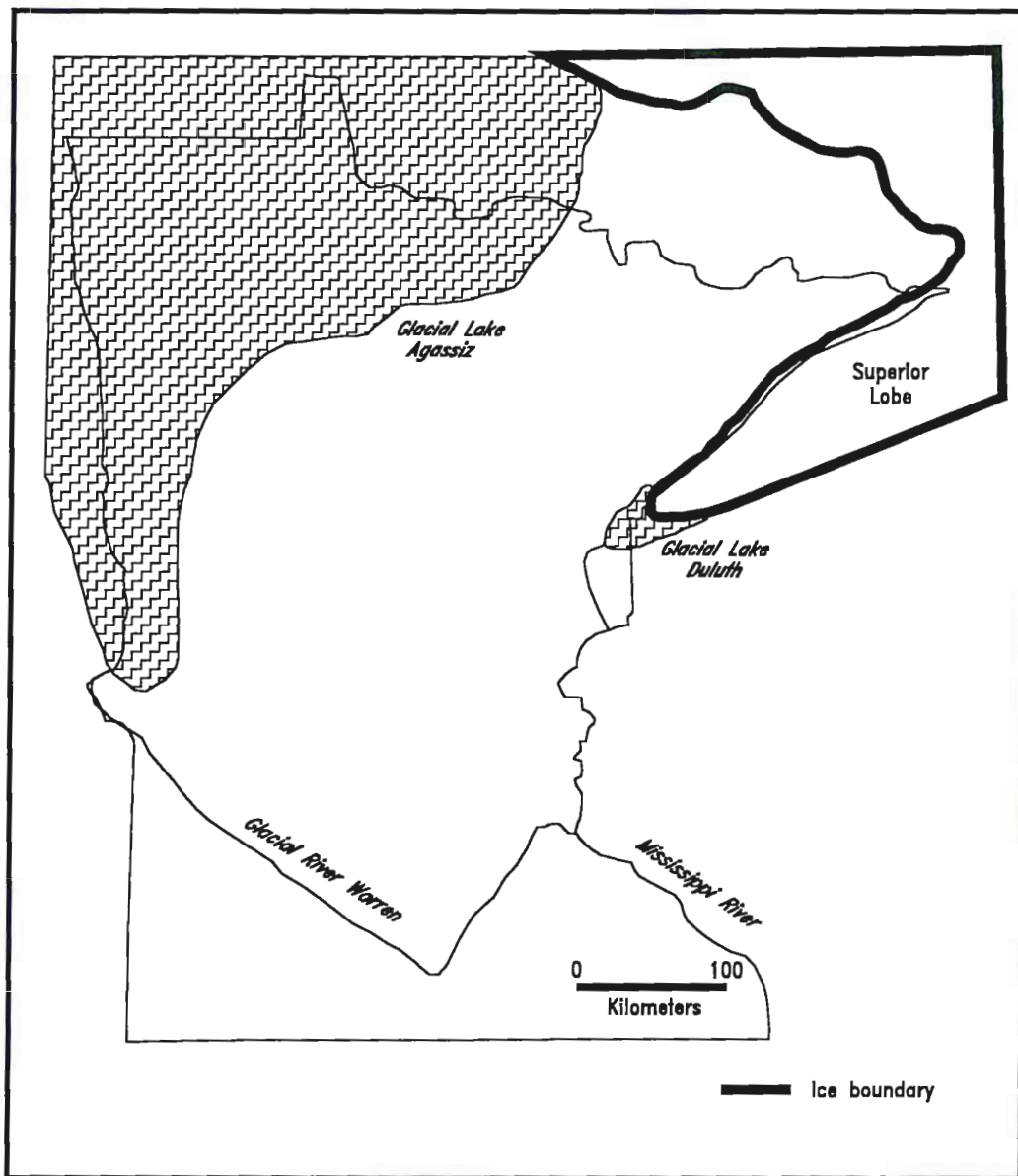


Figure 8. Glacial lobes and lakes at 10,000 B.P. (Modified from Mulholland and others, 1997).

VEGETATIONAL HISTORY OF NORTHEAST MINNESOTA

Several palynological studies have been conducted in northeast Minnesota to investigate the vegetational and climatic history of the area. Potzger (1953) investigated 15 sites in northeast Minnesota and adjoining Ontario, Canada. Although his data indicate vegetational change, the methods used are considered inadequate today. The investigation by Fries (1962) at Weber Lake is the first detailed palynological study in the area that used modern techniques. A comprehensive regional pollen stratigraphy for the state was compiled by Cushing (1967) for the late-glacial and early Holocene. Holloway and Bryant (1985) summarized the vegetational history of the Great Lakes Region for the last 20,000 years.

Currently northeast Minnesota is located in the transitional conifer-hardwood forest between the deciduous forest to the south and the boreal forest to the north (Fig. 9). This area lies within the Great Lakes-St. Lawrence forest region of Rowe (1959), the Lake Forest region of Weaver and Clements (1938), and the hemlock-white pine-northern hardwoods region of Braun (1950). This area of Minnesota is composed of a mosaic of conifers and deciduous broadleaf trees interspersed with wet prairies, marshes, conifer bogs and swamps, and open muskeg.

In northeast Minnesota, a late-glacial shrub tundra or open boreal forest developed with occasional stands of spruce or outliers of individual spruce trees as glacial ice receded (Fries, 1962; Baker, 1965; Cushing, 1967; Wright and Watts, 1969; Craig, 1972; Birks, 1981; Hill, Rapp, and Huber, 1985; Huber and Hill, 1987; Björck, 1990). By approximately 10,500 years ago, a shrub parkland dominated by

birch was established (Fries, 1962; Baker, 1965; Wright and Watts, 1969; Craig, 1972; Birks, 1981; Hill, Rapp, and Huber, 1985; Huber and Hill, 1987; and Björck, 1990). This was replaced by a conifer forest composed mostly of spruce and pine about 10,200 years ago (Fries, 1962; Cushing, 1967; Wright and Watts, 1969; Craig, 1972; Birks, 1981; Hill, Rapp, and Huber, 1985; Huber and Hill, 1987; Wonson-Liukkonen and Huber, 1987; and Björck, 1990). At approximately 9,000 years ago, a transition from the conifer forest to a mixed conifer-hardwood forest dominated by pine, birch, and alder occurred (Fries, 1962; Craig, 1972; Wright and Watts, 1969; Birks, 1981; Hill, Rapp, and Huber, 1985; Huber and Hill, 1987; Wonson-Liukkonen and Huber, 1987; and Björck, 1990). A succession from red and/or jack pine to white pine occurred at approximately 7,000 years ago (Weber Lake, Fries, 1962; Janssen, 1968; Wright and Watts, 1969; Craig, 1972; Maher, 1977; Huber and Hill, 1987; and Wonson-Liukkonen and Huber, 1987). Around 4,800 years ago, pine dominance decreased while spruce, birch, and other taxa increased (Fries, 1962; Wright and Watts, 1969; Craig, 1972; Maher, 1977; and Wonson-Liukkonen and Huber, 1987). Beginning about 1890, the natural vegetation of northeast Minnesota was altered by Euro-American settlement and deforestation. This is reflected by an increase in the pollen of ragweed and other disturbance and open-ground plants in the pollen record (Fries, 1962; Wright and Watts, 1969; Swain, 1973; Maher, 1977; Waddington, 1978; Huber and Hill, 1987; Wonson-Liukkonen and Huber, 1987; Rapp and others, 1995; and Huber, 1995b, 1998).

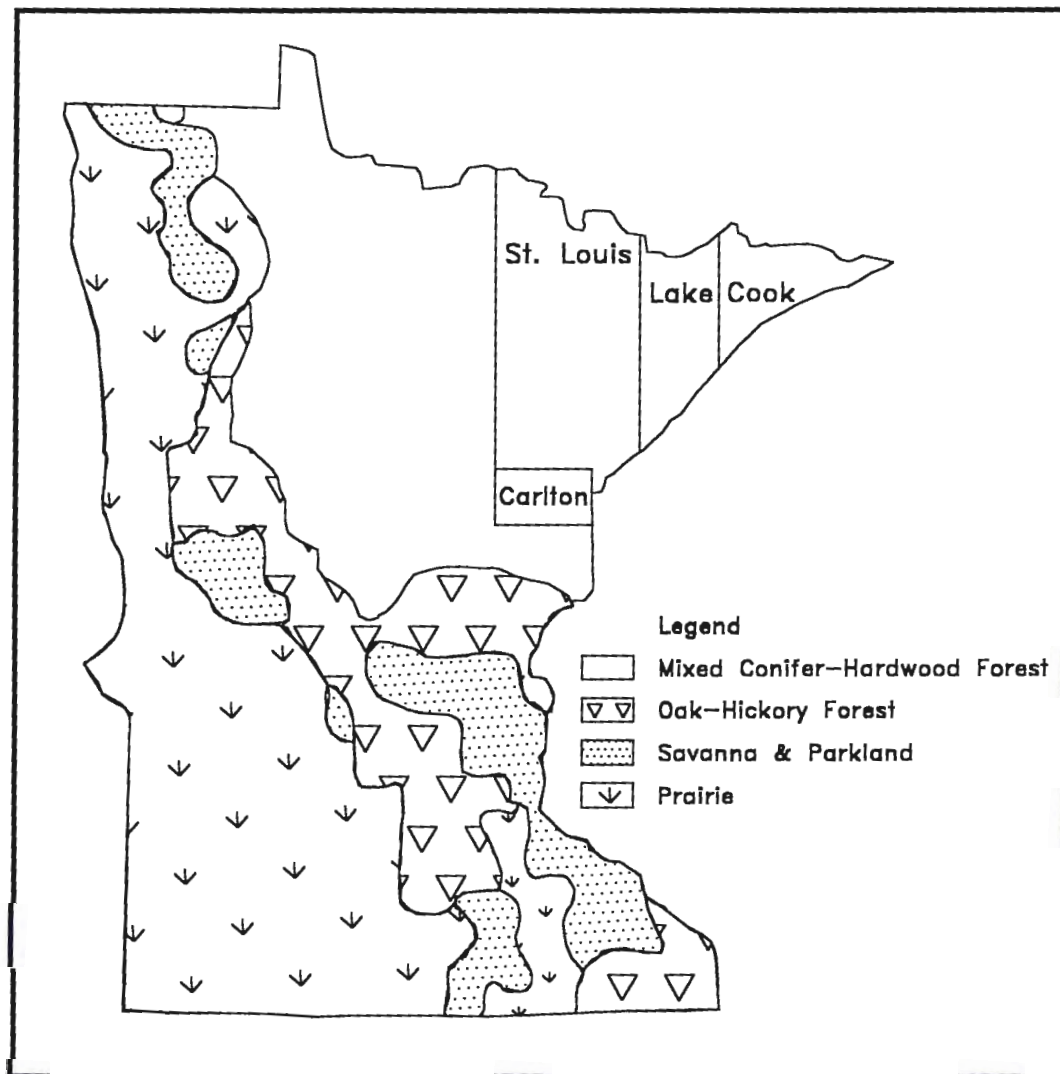


Figure 9. Major vegetation types of Minnesota.
(Modified from Cushing, 1965.)

REGIONAL POLLEN ASSEMBLAGE ZONES: DESCRIPTION AND CORRELATION

In 1967, Cushing defined regional pollen assemblage zones for Minnesota based on all pollen data available at the time in accordance with the Code of Stratigraphic Nomenclature. The zones are strictly biostratigraphic units without ecologic or climatic implications and may be time transgressive (Cushing, 1967). The regional pollen assemblage zones defined by Cushing only encompass the period of time from 15,000 to approximately 8,000 yr B.P. because of a lack of pollen data younger than 8,000 yr B.P. These regional pollen assemblage zones can be used to place local pollen sequences in northeast Minnesota in a temporal and spatial context. For the Arrowhead Region, Cushing (1967) defined four regional pollen assemblage zones. From oldest to youngest, they are the Compositae-Cyperaceae Assemblage Zone, *Betula-Picea* Assemblage Zone, *Picea-Pinus* Assemblage Zone, and *Pinus-Betula-Alnus* Assemblage Zone. Some investigators use their own designations.

Compositae-Cyperaceae Assemblage Zone

As defined, the Compositae-Cyperaceae assemblage zone is the oldest zone in northeast Minnesota (Fig. 10). The Compositae-Cyperaceae assemblage zone usually occurs as the first unit of pollen-bearing sediments above Wisconsin glacial drift (Cushing, 1967). This zone is characterized by high nonarboreal pollen (NAP) values (greater than 40%). Important NAP are Cyperaceae, *Ambrosia*-type, *Artemisia*, other

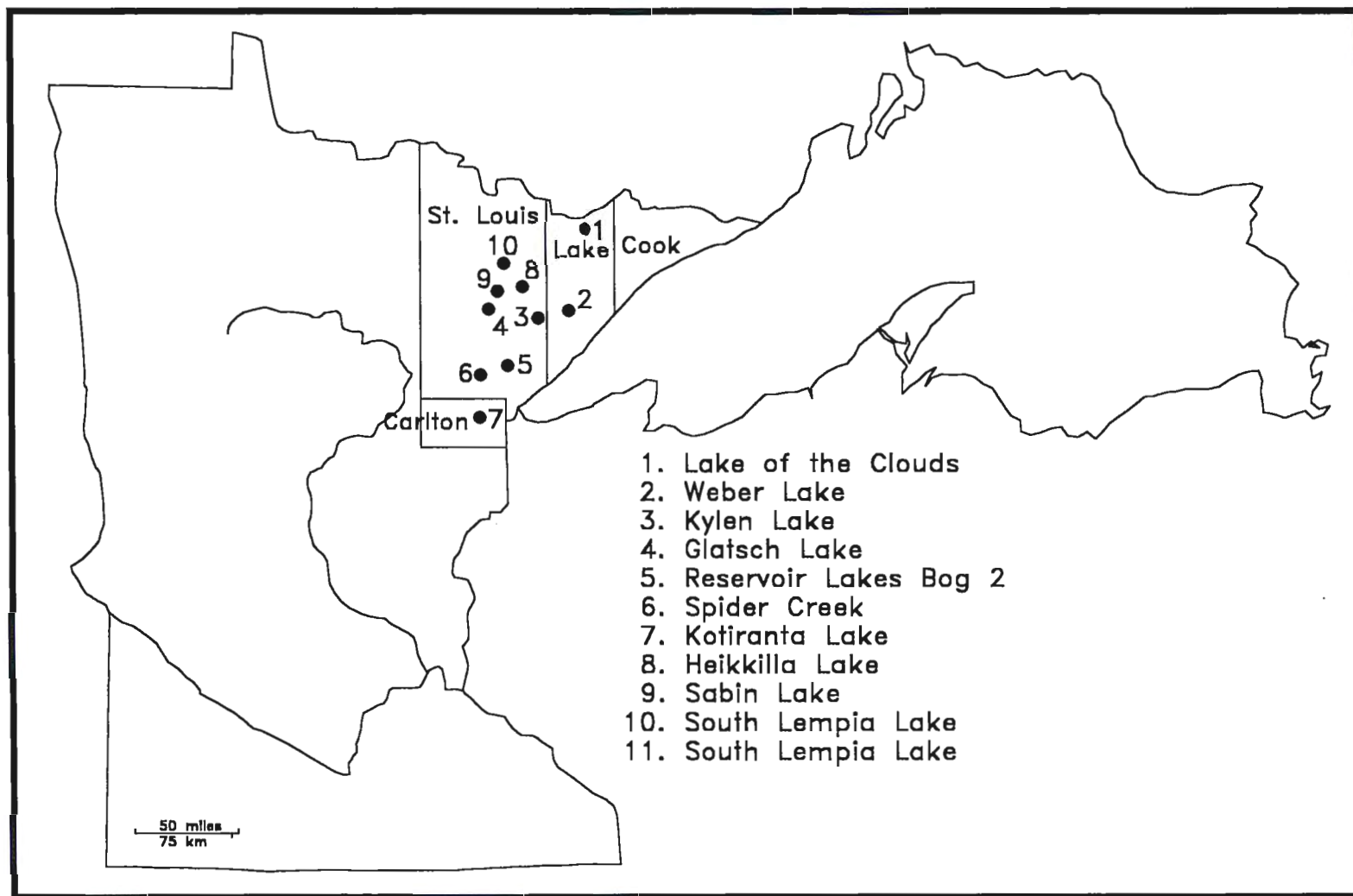


Figure 10. Compositae-Cyperaceae pollen zone locations.

Tubuliflorae, and Gramineae. Two other NAP types, *Urtica*-type and Ericaceae, may also be important. The most abundant arboreal pollen (AP) type is *Picea*; *Salix* is also important. Cushing (1967) positioned the upper boundary of this zone where NAP declines to less than 50%. At several sites in northeast Minnesota this zone is associated with macrofossils of *Dryas integrifolia*, *Salix herbacea*, and other plants indicative of tundra vegetation (Cushing, 1967). This zone may also indicate an open boreal environment, based on the work of Ashworth, Schwert, Watts, and Wright (1981) at a site near Norwood, Minnesota.

The Compositae-Cyperaceae assemblage zone dates from older than 10,500 yr B.P. (Fries, 1962) at Weber Lake, the type locality (Cushing, 1967) to 14,700 yr B.P. (Wright, 1972). Björck (1990) delineated equivalent zones at Heikkilla Lake, Sabin Lake, and South Lempia Lake that are older than 11,500 B.P. At Kotiranta Lake, this zone has a midzone date of 13,500 yr B.P. and a queried basal date of 16,150 yr B.P. (Wright and Watts, 1969). Craig (1972) estimated this zone to begin about 11,000 yr B.P. at Lake of the Clouds, based on sedimentation rates. This zone ranges from 15,850 to 12,000 yr B.P. at Kylen Lake (Birks, 1981). Baker (1965) rejected a basal date of 22,000 yr B.P. at Spider Creek because of the possibility that the radiocarbon sample was contaminated with dead carbon. The regional Compositae-Cyperaceae assemblage zone is also found at Glatsch Lake (Wright and Watts, 1969) and Reservoir Lakes Bog 2 (Hill, Rapp, and Huber, 1985; Huber and Hill, 1987).

***Betula-Picea* Assemblage Zone**

According to Cushing (1967), *Betula* is the dominant pollen type in the *Betula-Picea* assemblage zone (Fig. 11); the next most frequent is *Picea*; also of importance is *Salix* (>3%). Pollen of other trees and shrubs is found at less than 5%. NAP ranges from 20-40%: Cyperaceae and *Artemisia* are the major NAP taxa.

The type locality for the regional *Betula-Picea* assemblage zone is Zone 2 of core C:1, which is also from Weber Lake, Lake County, Minnesota (Fries, 1962). At Weber Lake, this zone is dated at 10,500 yr B.P. and 10,200 yr B.P. At Lake of the Clouds, this zone ends at approximately 10,300 yr B.P. (Craig, 1972). The *Betula-Picea* assemblage zone ranges from 12,000-10,700 yr B.P. at Kylen Lake (Birks, 1981). This zone or similar zones are also found at Glatsch Lake (Wright and Watts, 1969), Spider Creek (Baker, 1965), Heikkilla Lake and South Lempia Lake (Björck, 1990), Reservoir Lakes Bog 2 (Hill, Rapp, and Huber, 1985; Huber and Hill, 1987), and Lake Superior (Huber, 1993; 1994).

***Picea-Pinus* Assemblage Zone**

The *Picea-Pinus* assemblage zone (Fig. 12) is defined by Cushing (1967) according to the following criteria: *Picea* and *Pinus* combined exceed 50% of total pollen; they are the most abundant pollen types; and each are greater than 10%. Diploxylon *Pinus* is greater than 50%, *Larix* is greater than 1%, *Alnus* less than 3%, and NAP less than 20%. *Betula*, *Quercus*, *Fraxinus nigra*-type, and *Abies* are other important components, as well as, *Ulmus*, which is greater than 3%.

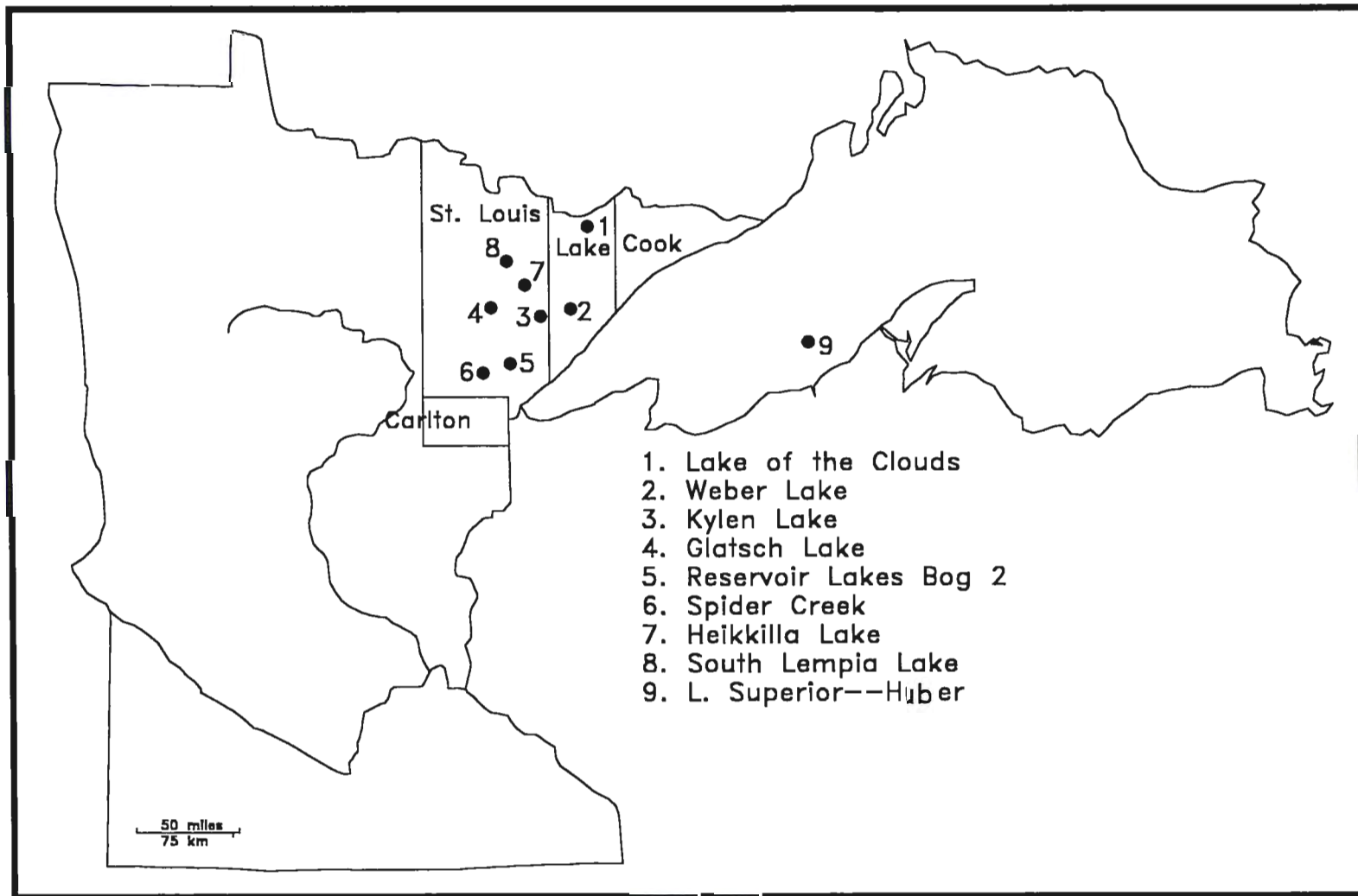


Figure 11. *Betula-Picea* pollen zone locations.

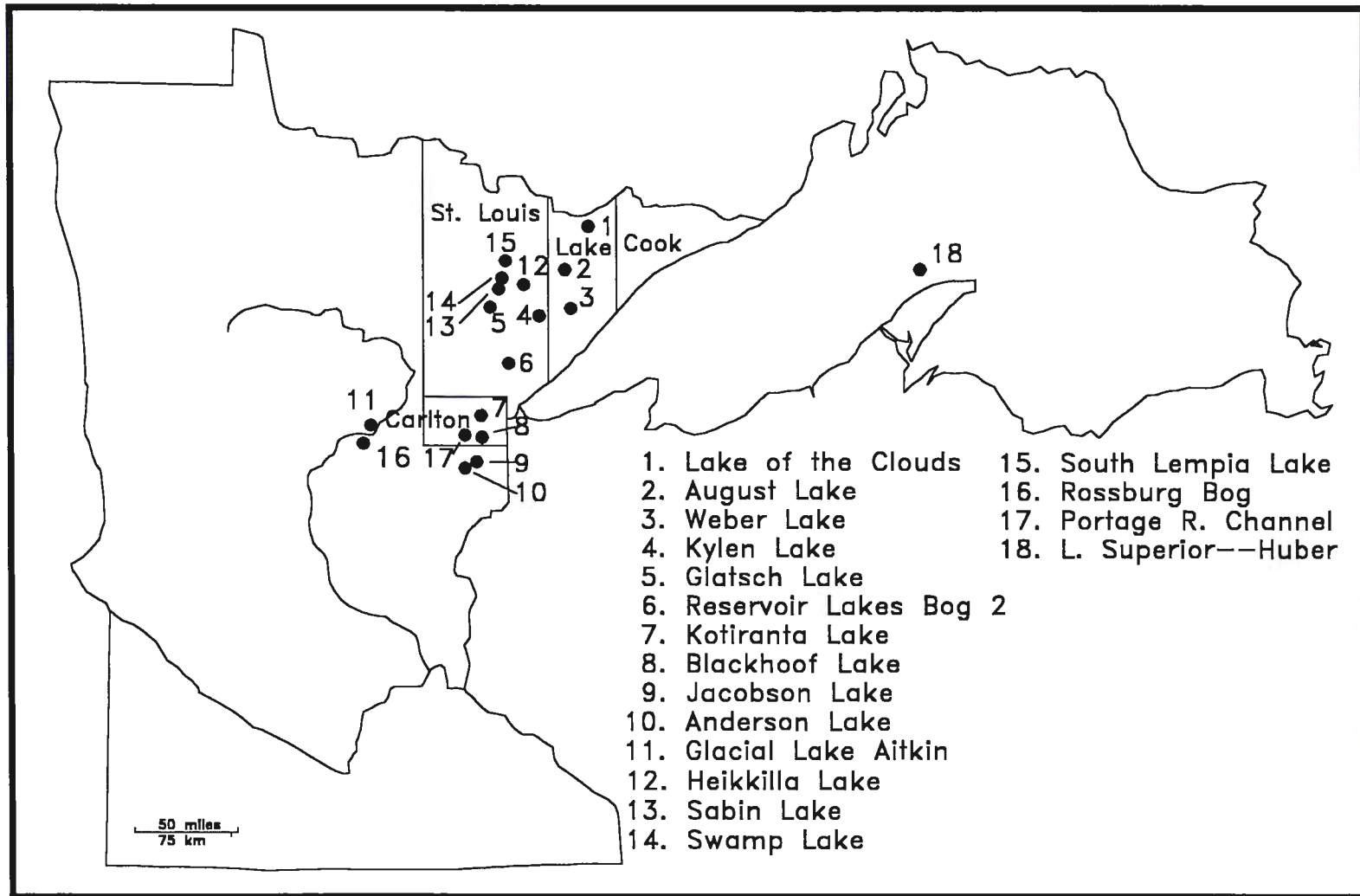


Figure 12. *Picea-Pinus* pollen zone locations.

Zone 3, core C:1 from Weber Lake is the type locality for the *Picea-Pinus* assemblage zone and dates from approximately 10,000-9,000 yr B.P. (Fries, 1962). This zone ranges from 10,700-9,250 yr B.P. at Kylen Lake (Birks, 1981) to approximately 10,300-9,200 yr B.P. at Lake of the Clouds (Craig, 1972). Combined pollen sequences from Heikkilla, Sabin, Swamp, and South Lempia lakes yield dates between 10,600-9,200 yr B.P. for this zone Björck (1990). The *Picea* peak at Glatsch Lake has been dated at approximately 9,750 yr B.P. (Wright and Watts, 1969). At the Portage River Channel (Bacig and Huber, 1993), the beginning of the increase in *Pinus* and the decrease in *Picea* has been dated at approximately 9,360 yr B.P. (date unpublished). This zone also occurs in cores from August Lake (Wonson-Liukkonen and Huber, 1987), Blackhoof Lake (Cushing, 1967), Kotiranta Lake (Wright and Watts, 1969), and Reservoir Lakes Bog 2 (Hill, Rapp, and Huber, 1985; Huber and Hill, 1987). The *Picea-Pinus* assemblage zone is also found at Anderson Lake, Jacobson Lake, and Rossburg Bog (Wright and Watts, 1969), and at Lake Superior (Huber, 1993; 1994). At Glacial Lake Aitkin (Farnham, McAndrews, and Wright, 1964), the *Picea-Pinus* assemblage zone occurs in the lower part of Zone 3 (Cushing, 1967).

***Pinus-Betula-Alnus* Assemblage Zone**

In the *Pinus-Betula-Alnus* regional pollen assemblage zone (Fig. 13), *Pinus* is the dominant pollen type, *Betula* is relatively important with values greater than 10%,

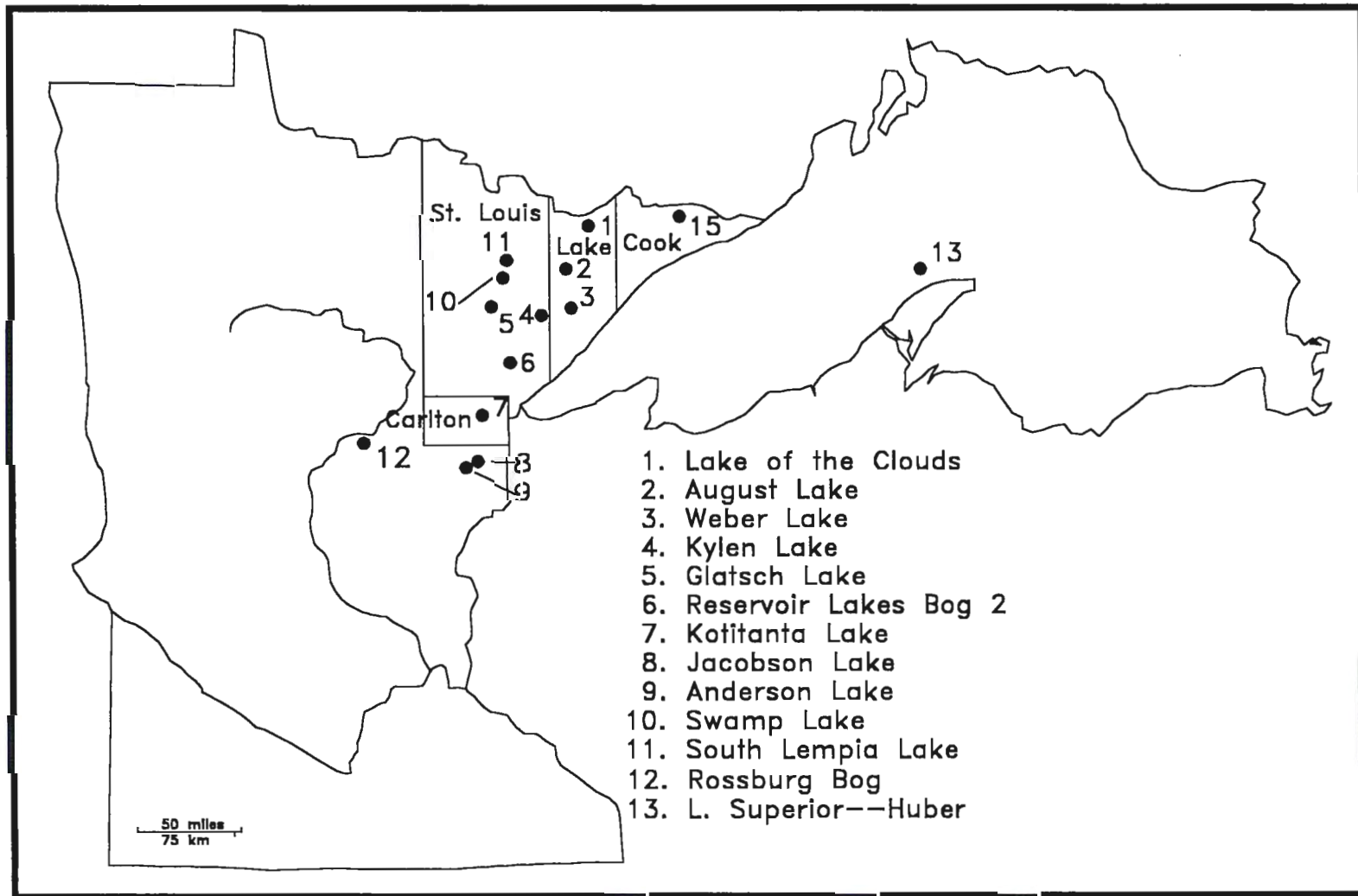


Figure 13. *Pinus-Betula-Alnus* pollen zone locations.

and *Alnus* is greater than 5%. *Abies* occurs at 1% or more and *Quercus* and *Ulmus* are less than 5%; NAP is less than 15% (Cushing, 1967).

At Weber Lake, Zone 4, core C:1 is the type locality for the regional *Pinus-Betula-Alnus* assemblage zone. This zone dates from about 9,000 to 7,000 yr B.P. at Weber Lake (Fries, 1962) and from 9,250 to 8,400 yr B.P. at Kylen Lake (Birks, 1981). Correlative zones at Lake of the Clouds date from 9,200-6,500 yr B.P. (Craig, 1972). This zone begins at 9,200 yr B.P. at Swamp Lake and South Lempia Lake (Björck, 1990). A similar pollen spectra has been dated at 8,000 yr B.P. from Lake Superior core LRTN-23P. The *Pinus-Betula-Alnus* assemblage zone is also found at August Lake (Wonson-Liukkonen and Huber, 1987), Glatsch Lake, Kotiranta Lake, Rossburg Bog, Anderson Lake, and Jacobson Lake (Wright and Watts, 1969), and Reservoir Lakes Bog 2 (Hill, Rapp, and Huber, 1985; Huber and Hill, 1987).

Other Assemblage Zones

Cushing (1967) did not establish regional pollen assemblage zones for pollen sequences occurring above the *Pinus-Betula-Alnus* assemblage zone because of the lack of data younger than 8,000 B.P. However, at least two biostratigraphic assemblage zones can usually be identified above the *Pinus-Betula-Alnus* assemblage zone. For convenience, these assemblage zones have been referred to as Upper Zone 1 and Upper Zone 2 by Huber (1992).

The Upper Zone 1 assemblage zone (Fig. 14) is found immediately above the *Pinus-Betula-Alnus* zone and is characterized by the prominence of *Betula* and *Alnus* and *Pinus* values of greater than 50%, with *Pinus strobus* becoming the dominant pine (Huber, 1992). An assemblage zone of this type is found at Lake of the Clouds (Craig, 1972) and August Lake (Wonson-Liukkonen and Huber, 1987). As a result of the high number of undifferentiated pine grains, this zone is not readily apparent at Reservoir Lakes Bog 2 (Huber and Hill, 1987). This type of zone is also found at Jacobson Lake (Wright and Watts, 1969), Weber Lake (Fries, 1962), and in Lake Superior (Maher, 1977; Huber, 1994).

The rise in white pine has been dated at approximately 7,200 yr B.P. at Jacobson Lake (Wright and Watts, 1969) and around 7,000 yr B.P. at Lake of the Clouds (Craig, 1972). At Myrtle Lake, the white pine rise occurred sometime before 6,000 yr B.P. (Janssen, 1968).

The Upper Zone 2 assemblage zone (Fig. 15) is characterized by an increase in *Picea*, although *Pinus*, *Betula*, and *Alnus* are still important (Huber, 1992). Zones equivalent to an Upper Zone 2 have been delineated at August Lake (Wonson-Liukkonen and Huber, 1987), Lake of the Clouds (Craig, 1972), Weber Lake (Fries, 1962), Kotiranta Lake (Wright and Watts, 1969), and Lake Superior (Maher, 1977; Huber, 1994).

A third zone that is an acme or peak zone characterized by the rise of *Ambrosia*-type pollen is also often occurring in northeast Minnesota (Fig. 16). This zone is commonly found in the upper sediment of pollen cores in the midwest and is

associated with deforestation and land clearance by pioneer settlement (Wright, 1971). In northeast Minnesota, a beginning date for the *Ambrosia*-type pollen rise is approximately 1890 (Maher, 1977).

An *Ambrosia*-type pollen rise occurs at August Lake (Wonson-Liukkonen and Huber, 1987), Reservoir Lakes Bog 2 (Huber and Hill, 1987), Weber Lake (Fries, 1962), Jacobson Lake (Wright and Watts, 1969), Burntside Lake, Shagawa Lake, Dogfish Lake, Meander Lake (Waddington, 1978), Lake of the Clouds (Swain, 1973), and Lake Superior (Maher, 1977; Huber, 1994).

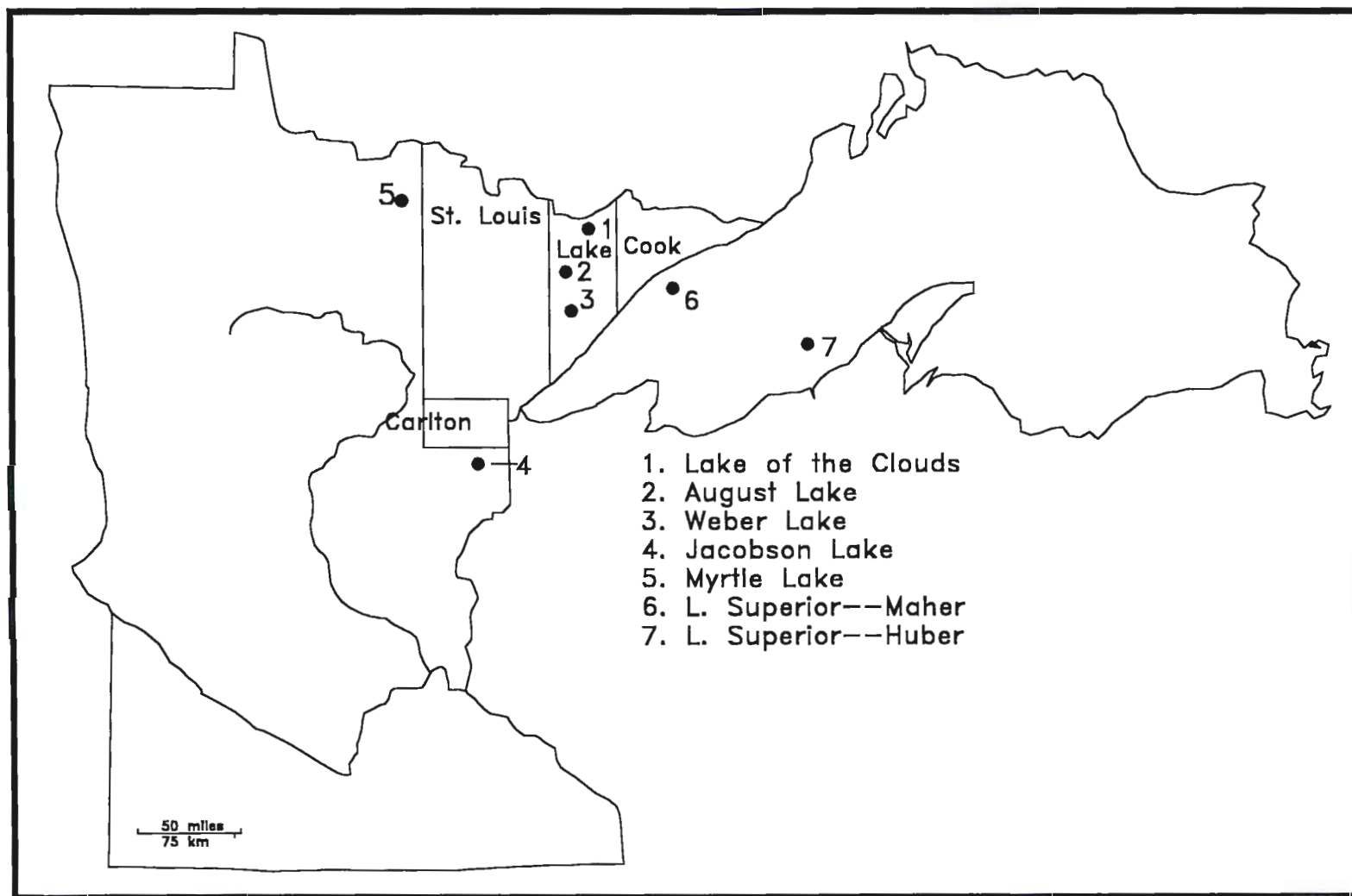


Figure 14. Upper Zone 1 pollen zone locations.

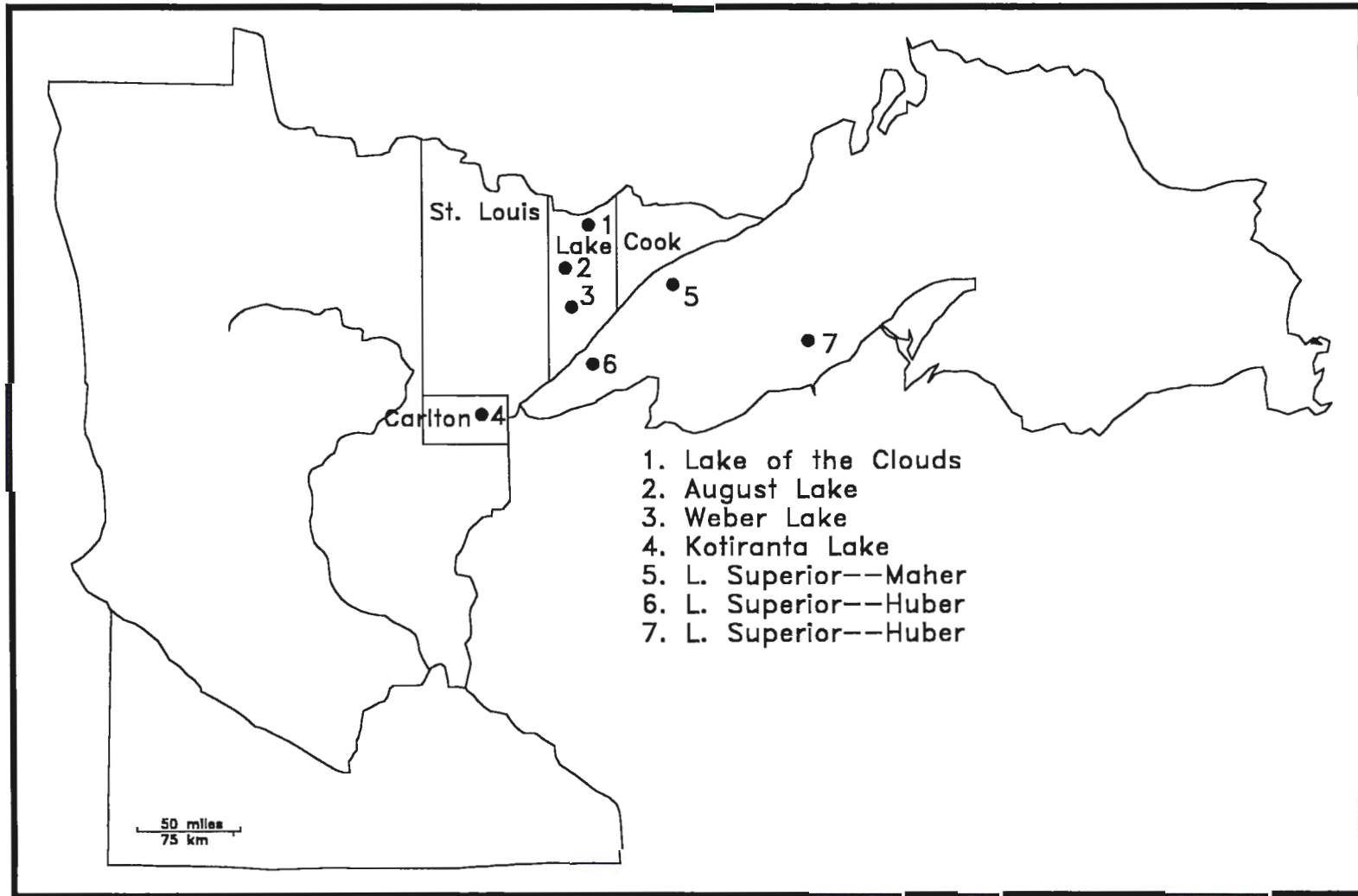


Figure 15. Upper Zone 2 pollen zone locations.

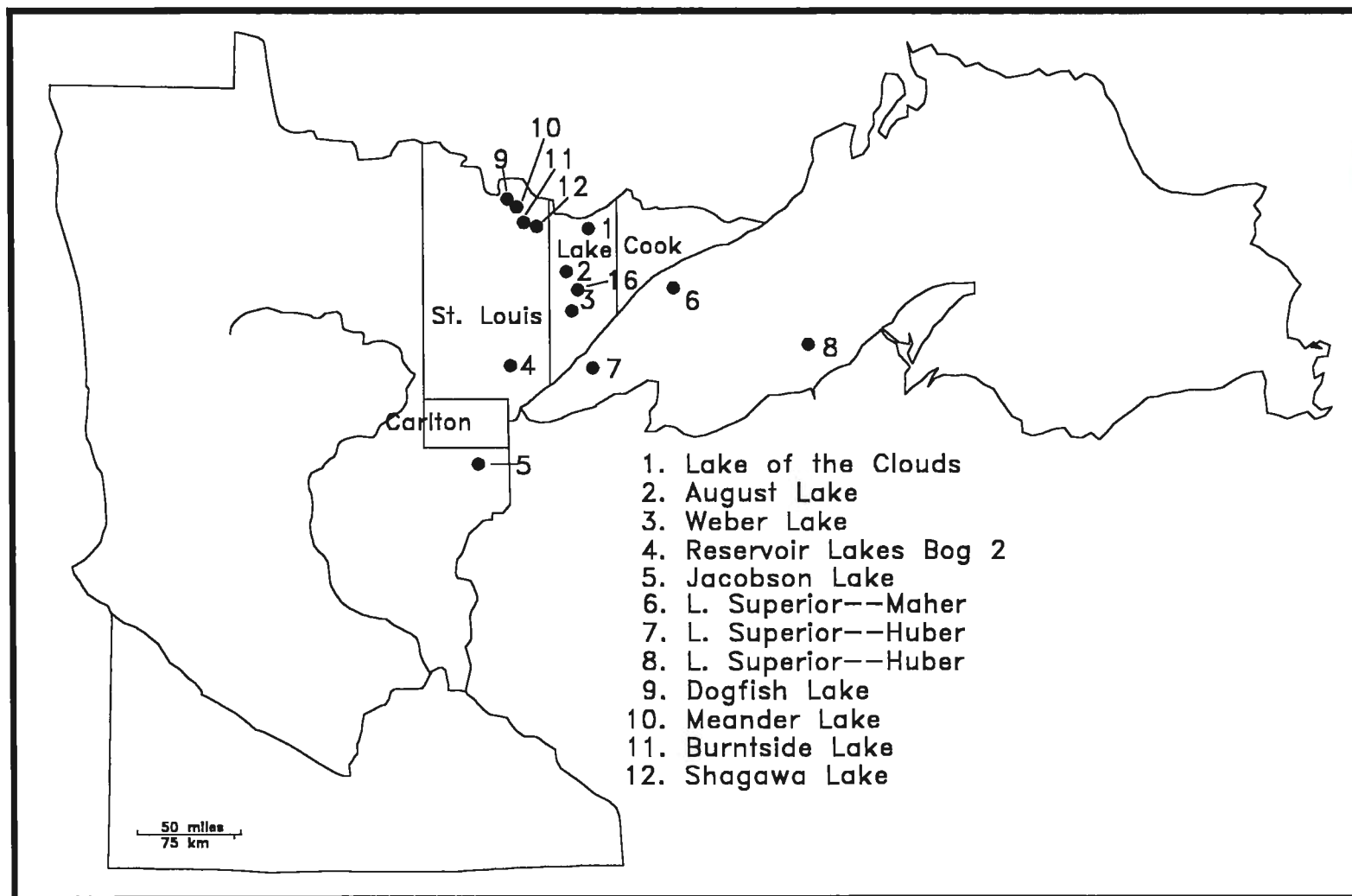


Figure 16. *Ambrosia* pollen zone locations.

PALEOECOLOGICAL STUDIES OF NONSILICEOUS ALGAE IN MINNESOTA

The majority of paleoecological investigations that have been carried out in Minnesota have relied heavily on pollen as the primary indicator of environmental change. In the past two decades, emphasis has been placed on the use of other organisms as paleoecological and paleoclimatic indicators (Williams, 1981); among these organisms are nonsiliceous algae (Van Geel, 1986).

Previous subfossil algal studies have generally concentrated on *Pediastrum* associated with extracted pollen. The green algal genus *Pediastrum* (Chlorophycophyta) is readily preserved in sediments and can also survive rigorous pollen-extraction techniques (Cronberg, 1986). Although they can be easily identified to the species level, in most algal studies *Pediastrum* is only identified to the genus level and is presented as a percentage of total *Pediastrum* (Cronberg, 1986). *Scenedesmus*, *Botryococcus*, *Tetraedron*, several types of resting spores, and numerous other taxa of nonsiliceous algae in addition to *Pediastrum* can be recognized in the subfossil record. Subfossil nonsiliceous algae found in conjunction with pollen can aid in paleoecological reconstructions (Cronberg, 1986). Figure 17 shows the locations of nonsiliceous algal studies that have been undertaken in conjunction with pollen investigations in Minnesota.

Crisman (1978) reviewed the data from six sites in Minnesota from which *Pediastrum* values were recorded as part of palynological investigations. The sites reviewed were Glacial Lake Aitkin (Farnham, McAndrews, and Wright, 1964), Anderson Lake (Wright and Watts, 1969), Lake Carlson and Kirchner Marsh

(Wright, Winter, and Patten, 1963), Weber Lake (Fries, 1962), and Wolf Creek (Birks, 1976). Crisman (1978) found that the late-glacial *Picea* (spruce) zone was characterized by a *Pediastrum* peak at all six sites, which he interpreted as indicating increased productivity that may be related to differences in nutrient release patterns of spruce versus pine watersheds. Elevated *Pediastrum* values associated with the late-glacial *Picea* zone have also been documented at Kylen Lake (Birks, 1981), Myrtle Lake (Janssen, 1968), Heikkilla, Sabin, and South Lempia lakes (Björck, 1990), and Reservoir Lakes Bog 2 (Huber, 1989).

Other nonsiliceous algae that survive pollen-extraction methods can provide additional information about the trophic history of a lake (Liukkonen and Huber, 1988). Oscillations in *Scenedesmus* values in lake-sediment cores have been interpreted to indicate fluctuations of nutrient influx at Reservoir Lakes Bog 2 (Huber, 1989). Huber (1995a) used algae to determine trophic status and nutrient conditions at Grand Mound Oxbow Lake. At Elbow Lake, a decrease in *Scenedesmus* indicates a change in nutrient influx that may be associated with Euro-American settlement (Huber, 1995b).

At Wolf Creek, there is a drastic decrease in *Pediastrum Boryanum* at the same time that Gramineae values increase and *Zizania aquatica* macrofossils occur (Birks, 1976). Birks (1976) does not discuss the possibility of a relationship between the Gramineae increase and the *Pediastrum Boryanum* decline. However, subsequent analysis of nonsiliceous algae in conjunction with wild rice lake pollen investigations is needed to determine if a relationship exists between the two.

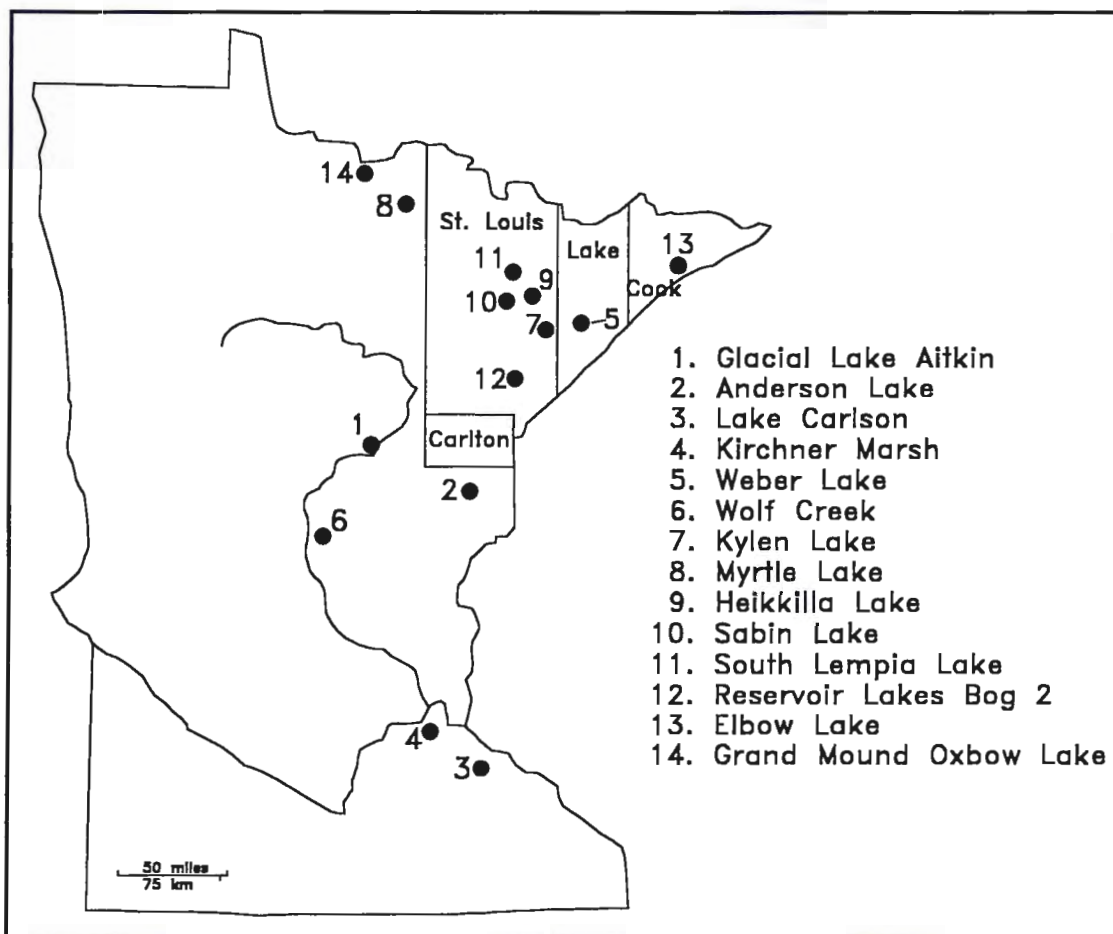


Figure 17. Location map of nonsiliceous algae studies in Minnesota.

III. THE ARCHAEOLOGICAL SEQUENCE IN NORTHEAST MINNESOTA

Pre-Paleoindian Period

There has been much discussion of the antiquity of humans in America (West, 1983; Dixon, 1993). At present there are few sites that are unarguably pre-Clovis in age. With the verification of the age of the Monte Verde site (1,000 years older than the generally accepted dates for Clovis) in southern Chile (Meltzer and others, 1997), most syntheses of pre-Clovis occupation of the Americas are obsolete. In addition to the approximately 12,500 year old occupation at Monte Verde, there is a good possibility that an even older occupation exists at Monte Verde (Meltzer and others, 1997). Currently, to my knowledge, no literature is available that address pre-Clovis in the Americas in light of the verification of Monte Verde. Although there is currently no evidence for it, it is possible that pre-Clovis people could have ventured into northeast Minnesota sometime after 16,000 yr B.P. based on the basal date at Kylen Lake (Banerjee, Lund, and Levi, 1979) if this date is correct and certainly by 13,500 yr B.P. when parts of central and northeast Minnesota were ice-free (Fig. 1).

Paleoindian Period

The Paleoindian tradition is subdivided into Early Paleoindian and Late Paleoindian based on differences in projectile point morphology. The Early Paleoindian is characterized by fluted points, such as Clovis and Folsom (Mason, 1997). Late Paleoindian is characterized by unfluted lanceolate points (Mason, 1997).

Early Paleoindian Period

In northeast Minnesota, information on early Paleoindian is limited but not absent (Mulholland and others, 1997). The scarcity of early Paleoindian artifacts has led some to believe that there was little to no occupation of northeast Minnesota prior to the "Late Paleoindian Period." The absence of early Paleoindian has often been attributed to environmental conditions at the end of the Pleistocene and the assumption that ice covered what is now the Arrowhead Region of northeast Minnesota. A pollen core recovered from Kylen Lake, St. Louis County, has a basal date of $15,850 \pm 240$ yr B.P. (Birks, 1981). Two other dates from the comparable lithologic boundary (Birks, 1981) in other cores from Kylen Lake are $16,500 \pm 1500$ yr B.P. (Banerjee, Lund, and Levi, 1979) and $16,050 \pm 230$ yr B.P. (Lund, unpublished data in Birks, 1981). Based on the Kylen Lake dates, at least part of southern St. Louis County was open for human occupation by approximately 16,000 years ago. Kotiranta Lake has a basal date of $16,150 \pm 600$ yr B.P. (Wright and Watts, 1969) and at Big Rice Lake the lowermost date from a pollen core is $12,040 + 540 / - 570$ yr B.P. (Huber, 1988). However, the dates from Kylen and Kotiranta lakes are standard radiocarbon dates and may be subject to error by the contamination of old carbon.

Based on palynological data, tundra-type vegetation was in the area immediately after deglaciation (Fries, 1962; Baker, 1965; Cushing, 1967; Wright and Watts, 1969; Craig, 1972; Birks, 1981; Hill, Rapp, and Huber, 1985; Huber and Hill, 1987; Björck, 1990). However, insect data associated with pollen and macrofossil data from a site near Norwood in south central Minnesota suggest an

open boreal environment with herbaceous vegetation (Ashworth and others, 1981). The climate is interpreted as having temperatures similar to those supporting boreal forest. The pollen spectra from the basal sediments suggest a tundra environment. However, the plant macrofossil and insect assemblages do not support this. Ashworth and others (1981) interpret the data from the Norwood site as indicating progressive community succession on stagnant ice terrain during deglaciation. A similar situation exists today at the terminal portion of the Klutlan Glacier, southwestern Yukon Territory (Ashworth and others, 1981).

Although relatively scarce, Early Paleoindian artifacts have been found in the Upper Great Lakes Region (Mulholland and others, 1997; Mulholland, 2000). At Island Lake, a Clovis point with the tip missing has been described by Romano and Johnson (1990). The Clovis point is a surface find made of Gunflint Silica, a local lithic material (Romano and Johnson, 1990). The base of a Folsom point was recently found near Britt, in St. Louis County, during a field survey (S.L. Mulholland, personal communication, 2000). A fluted point has also been found at Round Lake in Itasca County (Mulholland and others, 1997; Ross, 1997). Several fluted points have been found near Pine City, Minnesota (Ross, 1997). A possible Clovis point is also reported from the Otte site near Hurley Wisconsin (Mires, 1989). The point is reported as Clovis by Mires (1989), although Gordon Peters in Mulholland and others (1997) and Dudzik (1991) believe it to be Holcombe-like. The point is made from material identified as Hixton silicified sandstone. Hixton silicified sandstone is a material from west-central Wisconsin, near the town of Hixton.

In addition to fluted points, basally thinned lanceolate points known as Holcombe points have been associated with Early Paleoindian in the Upper Midwest (Mulholland and others, 1997). Several of these types of points have been recovered from the Holcombe Beach site (Mulholland and others, 1997). A basally thinned point base of Knife Lake siltstone was recovered from the Bearskin Point site on East Bearskin Lake (Mulholland and others, 1997). At the Brohm site in Thunder Bay, Ontario, several basally thinned points have been recovered according to Ross (personal communication in Mulholland and others, 1997). Ross (1997, p. 249) states that "a Holcombe classification for any points from the Brohm site is stretching the limits of point typology."

In southeast Wisconsin in Kenosha County at the Chesrow and associated sites, several basically lanceolate points atypical of other Paleoindian points have been recovered (Mason, 1997; Overstreet, 1993). The points are made of poor quality local raw materials and have been thermally altered (Overstreet, 1993). The Chesrow and associated sites have been defined by Overstreet (1993) as the Chesrow complex. Based on radiocarbon dates of cultural and non-cultural mammoth and mastodon remains and plant remains, the Chesrow Complex probably dates between 9,000 and 12,5600 yr B.P. (Dallman, Overstreet, and Stafford, 1996; Fredlund and others, 1996; Overstreet, 1993, 1996; Overstreet and Stafford, 1997; Overstreet, Joyce, and Wason, 1995; Overstreet and others, 1993)

The presence of the Island Lake Clovis point indicates that Early Paleoindians were probably in the area during a time of tundra-type vegetation between 12,000 and

11,000 B.P., if these points are coeval in time with Clovis points elsewhere in North America. The lack of fluted and/or basally thinned points associated with Early Paleoindian in northeastern Minnesota and northwestern Wisconsin may be the result of field conditions and survey bias rather than past population densities (Dudzik, 1991; Mulholland and others, 1997), as well as archaeological survey intensity (Ross, 1997). In northeast Minnesota, dense forest and bog cover make field surveys very difficult.

The subsistence pattern of Early Paleoindian in the Great Lakes Region is believed to be that of specialized big game hunters of extinct megafauna (Mason, 1981; 1997), although evidence of specialized big game hunting is limited in the upper Great Lakes Region. At the Holcombe site there is an association of extinct Barren Ground Caribou with Paleoindian (Mason, 1997). Few, if any, Paleoindian sites in northeast Minnesota have yielded faunal remains of any kind. Although a firm association of late Pleistocene megafauna has not yet been established with the Paleoindian Chesrow Complex, butchered mammoth and mastodon remains recovered in Kenosha County, Wisconsin (Overstreet, 1993; 1996) supports the hunting or scavenging of late Pleistocene megafauna by Paleoindians. Although there is evidence of the association of Early Paleoindian with extinct Pleistocene megafauna, it is probable that Early Paleoindians utilized a wide range of large and small animals (Mason, 1981). It is also likely that Early Paleoindians supplemented their diet with wild plant foods, birds, and fish (Mason, 1981). Although wild plant foods were

probably utilized, the lack of vegetable processing tools suggests that wild plant foods were not an important part of Paleoindian subsistence (Mason, 1981).

Late Paleoindian Period

The evidence for the presence of Late Paleoindian occupation in northeast Minnesota and surrounding areas is much more abundant than Early Paleoindian. Several sites and surface finds from the Late Paleoindian period have been found in northeast Minnesota, northwestern Wisconsin, and southern Ontario. The Late Paleoindian period is recognized by lanceolate and unfluted Plano-type projectile points. Numerous Plano-type projectile points have been recovered in the vicinity of the Reservoir Lakes north of Duluth (Steinbring, 1974; Harrison and others, 1995). Near Thunder Bay, Ontario, several Late Paleoindian sites have been reported (Julig, 1994; Phillips, 1988; Ross, 1997) that are Plano-affiliated. Late Paleoindian material has been recorded from numerous aceramic sites and surface finds within the Superior National Forest (Mulholland and others, 1997). At the Big Rice Site, two Plano points were recovered, a miniature Brown's Valley and an Agate Basin (Huber, 1987a). Two Paleoindian biface artifacts were recovered by the U.S. Forest Service at a small site at Cloquet Lake (G. R. Peters, personal communication, 2000). On McDougal Lake, the Misiano site has a Paleoindian component (Mulholland and others, 1997). Two Agate Basin points, two Scottsbluff point bases, and one probable Scottsbluff point base have been recovered from the Fish Lake Dam site (S.C. Mulholland, personal communication, 2000). Late Paleoindian surface finds have

also been reported from Basswood Lake, Fall Lake, Granite River, Hungry Jack Lake, Knife Lake, Moose Lake, Rose Lake, Sagnaga Lake, South Fowl Lake, Vermilion Lake, Whiteface Reservoir, and from the vicinity of Eveleth on the shore of Glacial Lake Aitkin (Mulholland and others, 1997).

Ross (1997) suggests that the term "Interlakes Composite" be used to describe the collective of four Late Paleoindian complexes in northeastern Minnesota and adjoining southern Ontario. The four complexes are (from west to east) the Lake of the Woods/Rainy River Complex, Quetico/Superior Complex, Lakehead Complex, and Reservoir Lakes Complex.

South of the Reservoir Lakes Complex, Late Paleoindian materials have been recovered from the Sucices site near Solon Springs, Wisconsin. Diagnostic artifacts from the Sucices site include a Knife Lake siltstone adze fragment, a Hixton Silicified Sandstone Scottsbluff/Eden preform base, and an oolitic chert Plainview base (Engseth, 1998). Near Gordon, Wisconsin, a Hixton Silicified Sandstone Agate Basin base was recovered from the Bowling Lane site (Engseth, 1998).

It is assumed that Plano people were big game hunters who hunted moose, caribou, and now extinct Pleistocene megafauna (Peters and others, 1983; Jelks, 1988; Peters and Motivans, 1985, Mulholland, 2000). Although little evidence exists, it is probable that their diet was supplemented by food plants (Jelks, 1988; Peters and Motivans, 1985). Several seeds, including *Chenopodium*, have been recovered from the Bearskin Point site (Mulholland, 1995), which suggests that plant foods may have been gathered for subsistence. The Paleoindian Tradition lasted until approximately

7,000 B.P. in northeast Minnesota (Peters and others, 1983; Peters and Motivans, 1985).

Although the prevailing theory is that Late Paleoindians utilized a big game hunting strategy, this theory may not be universally applicable. Data from the Sucies and Deadman Slough sites in northern Wisconsin and other sites in eastern North America indicate that the Late Paleoindians utilized a generalized foraging strategy. Recent faunal analysis by Kuehn (1998) indicates that white-tailed deer, black bear, porcupine, large-sized mammal (deer and possibly moose or black bear), medium-sized mammal (possibly raccoon, beaver, otter, or porcupine), turtle (softshell and painted), and indeterminate bird (possibly migratory waterfowl) were procured by Late Paleoindians at the Deadman Slough site. Kuehn (1998) also found indeterminate fish and indeterminate mussel remains at the Deadman Slough site. However, the condition and recovery context of these remains suggest they may be recent intrusions. At the Sucies site, white-tailed deer, beaver, large-sized mammal (most likely deer), medium-sized mammal, indeterminate mammal, painted turtle, water/box turtle, indeterminate turtle, and indeterminate fish were recovered (Kuehn, 1998). Preliminary faunal analysis of three sites in east-central Wisconsin (Kiesow Grove, Wohlt, and Russell Wohlt) indicate that white-tailed deer, beaver, muskrat, Blanding's turtle, softshell turtle, painted turtle, bird (probably waterfowl), and fish were being utilized by Paleoindians (Kuehn, 1998).

According to Kuehn (1998), the faunal remains from the above mentioned sites indicate that Late Paleoindians were exploiting a wide variety of environments using a

generalized foraging strategy. Thus, it is likely that Western Great Lakes Paleoindians were exploiting lake, river, and wetland habitats (Kuehn, 1998).

Archaic Period

In northeast Minnesota and the Upper Great Lakes area it is often difficult to distinguish the end of the Paleoindian from the beginning of the Archaic (Mason, 1981). The shift from the Late Paleoindian to Archaic is viewed by Mason (1981) as a transitional phase or interregnum between the Late Paleoindian Tradition and Late or Full Archaic Tradition. In northeast Minnesota, the Archaic Tradition extends from approximately 7,000 to 2,500 yr B.P. (Peters and others, 1983). The Archaic in northeast Minnesota is defined as Shield Archaic (Mason, 1981), although Steinbring (1974) argues that the Archaic materials from northeast Minnesota do not totally fit the description of Shield Archaic as put forth by J.V. Wright (1972). Mason (1981) believes that much of the Shield Archaic evolved in situ from the Late Paleoindian rather than being an intrusion of Archaic lifeways that developed elsewhere. The Shield Archaic is mostly found north of the Great Lakes and includes the entire north shore of Lake Superior (Mason, 1981). The name Shield Archaic is derived from the Canadian Shield, the geological formation which underlies most of its range (Dobbs, 1988; Mason, 1981).

In Minnesota, the Archaic Tradition is not well understood and most available information comes from private collections and surface finds (Dobbs, 1988). Relatively few Archaic sites have been excavated in northeast Minnesota with the

notable excavations of the Misiano site in Lake County and the Fish Lake Dam site in St. Louis County, Minnesota. Based on lithic materials, the Misiano site has a Paleoindian component which is estimated to date between 12,000 and 7,000 yr B.P. in this area. The site also has an Archaic component (7,000-2,000 yr B.P.). The site was apparently heavily used during the transition from Paleoindian to Archaic. G.R. Peters (personal communication, 2000) has interpreted the site to have been used for the construction of dugouts during this period of occupation.

The Fish Lake Dam site was initially investigated by Steinbring (1974) and is currently being excavated by Dr. S.C. Mulholland (Archaeometry Laboratory, University of Minnesota, Duluth). Several Raddatz points (Middle to Late Archaic), one Durst point (Later Archaic), one Adena point (Late Archaic), and two other side notched points have been recovered from the Fish Lake Dam site (S.C. Mulholland, personal communication, 2000). In addition to the Archaic points recovered, several copper artifacts have been recovered, including three knives, one large bead, several awls, and a hook, as well as flattened pieces of copper that may indicate copper working at the site (S.C. Mulholland, personal communication, 2000).

The paucity of Archaic sites in northeast Minnesota and the Upper Great Lakes has led some archaeologists to believe that population size during the beginning of the Archaic was less than during the preceding Late Paleoindian (Mason, 1981). According to Mason (1981), one reason for the paucity of Archaic archaeological sites in northeast Minnesota and elsewhere is explained by the Ritchie-Fitting Hypothesis. According to the Ritchie-Fitting model, much of the Great Lakes area was closed

coniferous forest poor in game and edible plants. It is also during this time that lake levels were lowered as a result of climatic warming (Anfinson and Wright, 1990; Mason, 1981; Webb, and Bryson, 1972; Watts, and Winter, 1966). Archaic sites originally located on shorelines would now be submerged and difficult to locate. Work by Bettis and Hajic (1995) has shown that many Archaic sites located in river valleys have been buried as fluvial systems have adjusted to climatic and vegetational change. In northeast Minnesota the apparent lack of Archaic sites, like fluted point Paleoindian sites, may be the result of field conditions and survey bias rather than past population densities. A reexamination of artifacts from sites in northeast Minnesota is needed to determine if previously unrecognized Archaic artifacts have been recovered. Recent examination of archived artifacts from several northeast Minnesota archaeological sites have yielded previously unrecognized Archaic points (S.L. Mulholland, and G.R. Peters, personal communication, 2000).

The Archaic Period is characterized by a decrease in tool size, quality of workmanship, and an increase in tool kit variety (Peters and others 1983; Dawson, 1983). Diagnostic artifacts include side-notched and stemmed projectile points (Mason, 1981, Dobbs, 1988; Stoltman, 1997) as well as other chipped stone tools. During this period native copper was used in the production of tools, such as knives, spear points, fish hooks, harpoon heads, awls, and beads (Mason, 1981; Peters and others, 1983; Peters and Motivans, 1985; Stoltman, 1997).

The use of copper technology was originally assigned to the poorly defined as the "Old Copper Complex" (Mason, 1981; Dobbs, 1988; Gibbon, 1998). Old Copper

is now recognized as a widespread technological complex that cross-cuts a number of Archaic societies (Mason, 1981; Dobbs, Gibbon, 1998). See Gibbon (1998) for a review of Old Copper in Minnesota.

A shift also occurred to the hunting of smaller game animals and a dependence on fish and more food plants (Anfinson and Wright, 1990; Peters and Motivans, 1985; Peters and others, 1983; Mason, 1981). According to Stoltman (1997, p. 112), one of the defining characteristics of the Archaic Tradition is "subsistence based entirely upon the hunting and gathering of modern flora and fauna." Widespread burial of the dead also begins in the Archaic (Stoltman, 1997; Mason, 1981).

Initial Woodland Tradition

The Woodland Tradition is commonly defined by three traits: pottery, burial mounds, and horticulture (Stevenson and others, 1997; Anfinson and Wright, 1990; Gibbon, 1986; Mason, 1981). Mason (1981, p. 202) adds a fourth trait in defining the Woodland Tradition, "an interrelated series of new artifacts and style shifts in old ones." The Woodland Tradition is commonly divided into three periods or stages: Early, Middle, and Late (Stevenson and others, 1997; Anfinson and Wright, 1990; Mason, 1981). However, in northeast Minnesota, the Woodland Tradition does not fit well into three periods or stages. There is very little evidence of Early Woodland artifacts in Minnesota and what is present has been found stratigraphically associated with Middle Woodland materials (Gibbon, 1986). According to Gibbon (1986, p.

89), "Minnesota apparently lacks both Early Woodland complexes and a meaningful Early Woodland time period." A few archaeologists in the state have recognized this absence by referring to the ca. 200 B.C.-A.D. 900 time period as "Initial Woodland." In northeast Minnesota, the Woodland Tradition is divided into the Initial Woodland Period and the Terminal Woodland Period (Peters and Motivans, 1985; Mulholland, 2000). The Initial Woodland Period is estimated to begin about 2,500 yr B.P. (G.R. Peters, personal communication, 1999) and last until 1,300 yr B.P. (Peters and others, 1983).

The change from Late Archaic to Initial Woodland was slow. No sudden transformation occurred (Stevenson and others, 1997; Anfinson and Wright, 1990; Mason, 1981). According to Anfinson and Wright (1990, p. 218), "For the most part, Early Woodland cultures are simply Late Archaic cultures with pottery."

In northeast Minnesota, the Initial Woodland is represented by the Laurel culture (Peters and Motivans, 1985; Peters and others, 1983; Mason, 1981; Stoltman, 1973). Laurel pottery was tempered with crushed rock and had pointed or conical bases (Peters and Motivans, 1985; Anderson, 1979; Mason, 1981). Laurel pots had smooth exteriors with decorated rims (Peters and Motivans, 1985; Mason, 1981; Stoltman, 1973). Laurel pottery was made by rolling clay into small coils that were placed on top of each other to form a pot. A smooth rock was held on the inside of the pot and a wooden paddle was used on the outside to smooth the surfaces of the pot. The pots were then fired for use (Peters and Motivans, 1985). It has been suggested that pottery first appeared in northeast Minnesota to facilitate the parching

of wild rice (G.R. Peters, personal communication, 1994). According to Brown (1986), the use of pottery in northern Minnesota was the result of a change in subsistence rather than a temporal mark. The construction of pottery and burial mounds indicate an increase in population and may reflect the utilization of wild rice as a major food source (Dawson, 1983; Rajnovich, 1984).

During the Initial Woodland Period there was a shift to the utilization of more diverse food resources. Laurel people were hunters and gatherers who probably focused on a seasonal rhythm (Stoltman, 1973; Mulholland, 2000). They hunted large and small animals, fished, and were more dependent on plant foods, such as maple sugar, berries, and wild rice (Peters and Motivans, 1985). Large game probably consisted of caribou, moose, deer, and bear; smaller game included as porcupine and beaver (Mason, 1981).

Laurel lithics include numerous end-scrapers and notched and stemmed projectile points (Stoltman, 1973; Mason, 1981). Notched net-sinkers (Mason, 1981) and harpoons (Stoltman, 1973; Mason, 1981) were also used by Laurel people, as were beaver-incisor knives (Stoltman, 1973; Mason, 1981). Native copper continued to be used in the manufacture of tools (Peters and Motivans, 1985; Peters and others, 1983; Stoltman, 1973; Mason, 1981). An increase in numbers of drills, awls, small scrapers, and wedges indicate a woodworking technology (Peters and others, 1983; Peters and Motivans, 1985). Bone and antler were also utilized in the manufacture of tools (Peters and Motivans, 1985; Stoltman, 1973; Mason, 1981).

Terminal Woodland Tradition

The Terminal Woodland Tradition is characterized by the appearance of three new cultures: Blackduck, Selkirk, and Sandy Lake (Peters and Motivans, 1985). The Terminal Woodland begins at approximately 1,300 yr B.P. (Peters and others, 1983; Anfinson and Wright, 1990) and ends at approximately 400 B.P. (1600 A.D.) when contact with French explorers occurred (Peters and others, 1983; Peters and Motivans, 1985; Mason, 1981). The differences in these cultures is based on pottery.

The Blackduck culture spans from approximately 1,300 yr B.P. to European contact along the north shore of Lake Superior (Mason, 1981). It is believed that Blackduck people were an Algonquian speaking group related, but not ancestral to, the Ojibwa (Lugenbeal, 1979). According to G.R. Peters (personal communication, 2000), they may have been related to the Sautaux. Blackduck sites are found from northern Lake Huron to Manitoba (Mason, 1981). In northeast Minnesota, the transition from Initial Woodland Laurel ceramics to Terminal Woodland Blackduck ceramics may have transpired without an intervening ceramic complex (Anfinson and Wright, 1990). Based on the location of Blackduck sites near major wild rice stands, the presence of ricing jigs at Blackduck sites, and the recovery of wild rice grains from Blackduck archaeological sites, intensive wild rice utilization is inferred (Anfinson and Wright, 1990; Peters and Motivans, 1985). Horticulture has not been established in northeast Minnesota, although a quasi-agriculture became established around the harvesting of wild rice (Mason, 1981).

Blackduck pottery is round-bottomed and globular (Lugenbeal, 1979; Mason, 1981). It has rounded shoulders, a moderately constricted neck, a moderately to very slightly excurve rim, and a tendency towards a very broad splayed rims (Mason, 1981). Decorations on the rim and/or neck are dominated by impressions of a cord-wrapped stick (Anderson, 1979; Mason, 1981). Circular punctates may also occur (Mason, 1981). There is enough difference in Blackduck pottery over time to divide the Blackduck pottery into an early and late phase (Mason, 1981).

Contemporaneous with the Blackduck culture was the Selkirk culture (Anfinson, 1979; Mason, 1981; Peters and Motivans, 1985). The Selkirk culture is also thought to be associated with Algonquian speakers, perhaps prehistoric Cree (Anfinson, 1979; Mason, 1981; Peters and Motivans, 1985). Selkirk ceramics appear in northeast Minnesota between 1,200 yr B.P. and 1,150 yr B.P.

Like Blackduck, Selkirk pottery was round-bottomed and globular (Anfinson, 1979; Mason, 1981; Peters and Motivans, 1985). Selkirk pottery is decorated only on the rim with punctate designs (Anfinson, 1979). Unlike other contemporaneous cultures, Selkirk ceramics included plates and bowls (Dawson, 1983).

According to Jenks (1977), the Sandy Lake culture is the ancestor to the Assiniboine and the northern Sioux. Peters and Motivans (1985) associate them with the ancestors of the Yankton Sioux. Sandy Lake ceramics first appear about 1,100 yr B.P. in northern Minnesota (Anfinson and Wright, 1990). The headwaters of the Mississippi River has the largest known concentrations of Sandy Lake materials (Birk, 1979).

Sandy Lake pottery is also round-bottomed (Peters and Motivans, 1985) but has straight sides (Johnson, 1988). Sandy Lake ceramics are usually undecorated (Cooper and Johnson, 1964) except on occasion on the interior lip (Stevenson and others, 1997). Sandy Lake pottery was grit tempered in northern areas and shell tempered to the south (Birk, 1979).

The lifeways of Terminal Woodland people were similar to that of Initial Woodland people (Mason, 1981). The advent of the bow and arrow occurred at approximately the beginning of the Terminal Woodland based on the appearance of small triangular points in many Terminal Woodland archaeological sites (Peters and Motivans, 1985; Mason, 1981; Anfinson and Wright, 1990). At this time there is also evidence, such as ricing jigs and pottery, for the increased use of wild rice (Anfinson and Wright, 1990; Stevenson and others, 1997). The Terminal Woodland Period ends at approximately 1600, when contact with French explorers occurred (Peters and Motivans, 1985; Mason, 1981).

Big Rice site is one of the major Woodland Tradition sites in northeast Minnesota. It was inhabited almost continually from the Initial Woodland into the Historic Period (Peters and Motivans, 1984; Peters and Motivans, 1985). The Big Rice site contains Laurel, as well as Blackduck, Selkirk, and Sandy Lake ceramics (Peters and Motivans, 1985; Valppu, 1989). The site stratigraphy is quite complex because of overlapping ricing jigs and parching pits (Rapp, Allert, and Peters, 1990). At the Big Rice site, a radiocarbon date of $1,670 \pm 45$ yr B.P. was obtained from a Laurel wild rice parching pit (Rapp, Allert, and Peters, 1990). Four other dates on

wild rice grains from the Big Rice site are: $1,910 \pm 100$ yr B.P., $2,040 \pm 100$ yr B.P., $2,072 \pm 90$ yr B.P., and 600 ± 60 yr B.P. (Valppu and Rapp, 2000). Over 8,800 sherds, 70 lithic tools, and almost 2,000 waste flakes were recovered during the first field season (Peters and Motivans, 1984). Similar numbers of artifacts were recovered in subsequent seasons. At present, over 50,000 sherds have been recovered from the Big Rice site (G.R. Peters, personal communication, 1994). Finished copper tools and modified copper were recovered from the Big Rice site, although no raw copper was found (Rapp, Allert, and Peters, 1990).

Faunal remains recovered from the 1983 field season include large and small mammal bones, bird, turtle, fish, land snail, and mussel shell (Penman, 1984). Most of the bone was too deteriorated to identify to species although deer and moose remains were identified. Identifiable small mammals include snowshoe hare, beaver, porcupine and muskrat. Several birds identified to species are migratory, such as Canada goose and mallard (Penman, 1984), which suggests a fall occupation of the site. In addition to the faunal material, several taxa of flora have been recovered from the site (Valppu, 1989). The three most abundant taxa are lambsquarters or goosefoot, bedstraw, and wild rice (Valppu, 1989). Other taxa include American plum, raspberry/dewberry, chokecherry, elderberry, juneberry, knotweed or smartweed, sedge, bush honeysuckle, grass, balsam fir, and spruce (Valppu, 1989).

According to Dr. S.C. Mulholland, the Fish Lake Dam site, which is currently undergoing excavation, contains a Woodland component. Woodland materials recovered so far include unfired clay, fired trim pieces of clay, and several pieces of

pottery. One ceramic piece has been identified as Sandy Lake and a rim sherd has been tentatively identified by G.R. Peters as Laurel (Mulholland, personal communication, 2000).

IV. NATIVE AMERICAN USE OF WILD RICE

Zizania Aquatica L. (WILD RICE): THE PLANT

The plant *Zizania aquatica* is known most widely by its common name "wild rice." In the past many other names have been used for *Zizania aquatica*. Among these are Indian Rice, Canadian rice, water oats, water rice, tuscarora, and manomin or manoomin (Dore, 1969; Vennum, 1988). In French the plant was often referred to as "folle avoine," which means wild oats (Taube, 1951; Dore, 1969; Vennum, 1988) or fools oats (Vennum, 1988).

There is much discussion in the literature about which species and which varieties of wild rice actually grow in Minnesota. There argument is whether two separate species of wild rice or two varieties of one species grow in the state. *Zizania aquatica* is the scientific name most commonly used in the archaeological literature. However, two distinct species of wild rice are currently recognized by plant taxonomists, *Zizania aquatica* and *Zizania palustris* (Dore, 1969; Borman, Korth, and Temte, 1977). Since the proper scientific terminology of wild rice has not been resolved, the name *Zizania aquatica* is used here to remain consistent with the archaeological literature.

Wild rice is an annual plant that requires reseeding each year. The seeds germinate in the spring (Taube, 1951; Dore, 1969; Borman, Korth, and Temte, 1977) from mid- to late-April when water temperature reaches about 4°C (Vennum, 1988). The leaves reach the surface and float in late May or June. This is known as the floating stage. Stalks emerge and grow to 2-3 m above the water in midsummer

(July) (Taube, 1951; Dore, 1969; Borman, Korth, and Temte, 1977; Vennum, 1988).

The stalks are thick, spongy, and hollow and divided by nodes. Tillers and leaves emerge from these nodes (Dore, 1969; Vennum, 1988). In mid July a shoot or spikelet emerges from each stalk that bears the flowering portion of the stalk. By August, a pyramid-shaped panicle forms at the top of the stalk. The lower portion of the panicle has spreading branches bearing the male or staminate flowers. Above these are the more erect pistillate or female flowers, which will become the wild rice grains (Moyle, 1944; Taube, 1951; Dore, 1969; Borman, Korth, and Temte, 1977; Vennum, 1988).

The female flowers mature from the top down over about a two week period. As the panicle matures, pollination occurs. In wild rice, unlike most other grasses, the anthers containing the pollen occur below the female flowers making it necessary for the pollen to rise up to the female flower. This ensures cross-pollination, although in extreme cases wild rice can self pollinate (Dore, 1988; Vennum, 1988). Wild rice is, for the most part, wind pollinated, although birds, bees, and other insects may become pollen vectors (Vennum, 1988). After pollination is completed, the male flowers die and fall off. Each spikelet has one seed that is covered by a palea (lower bract) and an awned lemma (upper bract). After pollination, the grains begin to build up the white starch content. This is called the milk stage.

Wild rice grains ripen over a 10-14 day period in late August through mid-September. If the wild rice grains are not harvested they fall off the plant. When the seed hits the water surface it falls quickly to the bottom. The seed is directed by the

rudder-like awn. The seed usually lodges in the sediment close to the parent plant (Moyle, 1944; Dore, 1969; Vennum, 1988). Wild rice seeds may remain viable for over five years (Borman, Korth, and Temte, 1977).

Wild rice is a shallow rooted plant (Dore, 1969; Borman, Korth, and Temte, 1977; Vennum, 1988) composed of several horizontal rootlets (Dore, 1969). Unlike land plants and other grasses, wild rice roots do not have root hairs. On wild rice plants occurring in deep water or very soft sediments, side roots may develop from higher nodes, similar to the prop roots in corn (Dore, 1969). As a result of the relatively short root system, wild rice can be easily uprooted by an increase in water level during the floating leaf stage (Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988).

Wild rice is a nonpersistent emergent (Eggers and Reed, 1997) with specific habitat requirements (Dore, 1969, Borman, Korth, and Temte, 1977). Wild rice grows best in 0.3-1 m of water (Moyle, 1944; Dore, 1969, Borman, Korth, and Temte, 1977; Eggers and Reed, 1997), although it will grow in shallower water and in water up to 3.5 m in depth (Dore, 1969; Vennum, 1988). Wild rice is commonly found in marshes, lakes, ponds, and streams/rivers (Eggers and Reed, 1997). However, it grows best in lakes with flowing water and streams/rivers (Moyle, 1944; Dore, 1969, Borman, Korth, and Temte, 1977; Vennum, 1988). Wild rice stands grow best when water chemistry has a pH of 6.8-8.8, a sulfate concentration of less than 10 ppm, and alkalinity between 5 ppm and 250 ppm (Borman, Korth, and Temte, 1977). The best substrate for wild rice is silt or organic rich sediment, but it

will grow on a wide variety of substrates (Moyle, 1944; Dore, 1969, Borman, Korth, and Temte, 1977; Vennum, 1988; Eggers and Reed, 1997).

Wild rice most commonly occurs in nearly pure continuous stands (Moyle, 1944; Dore, 1969). The yield of any individual rice stand is quite variable over time. However, in any given four year period, there is a tendency for one bumper crop, two mediocre to fair crops, and one crop failure (Jenks, 1900; Moyle, 1944; Vennum, 1988).

In overall nutritional value, wild rice is better than the introduced cultivated cereals (oats, barley, wheat and rye) and compares favorably with corn. According to Vennum (1988), wild rice is more nutritious, as a whole, than any other available grain, vegetable, animal, or fruit source that occurred naturally in the traditional Native American diet. Wild rice is extremely rich in carbohydrates, richer than corn, and is easily converted to energy by the body. Wild rice is also low in fat, contains protein required for growth, and is easily digested. It is rich in vitamin B, riboflavin, thiamin, and several minerals (Vennum, 1988).

ETHNOGRAPHIC DATA

Traditional Wild Rice Processing

In order to utilize wild rice as a food it must be collected, dried, parched, and dehusked. According to ethnographic accounts (Jenks, 1900; Densmore, 1928; Dore, 1969; Vennum, 1988), a few weeks before harvest, when the rice was in its milky stage, the panicles of wild rice were bound in a loop with strips of basswood (Jenks, 1900; Densmore, 1928; Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988). Each person had a characteristic style of binding, indicating ownership (Jenks, 1900; Densmore, 1928; Dore, 1969; Vennum, 1988). The tying of the bundles was done in rows making the wild rice stand appear similar to a field of grain with its rows of shacks (Taube, 1951). At maturity the bundles were unbound and the wild rice beaten with a pole over a canoe to gather the grain (Jenks, 1900; Densmore, 1928; Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988). In some instances the bundles were cut off and saved for later processing (Jenks, 1900; Dore, 1969; Vennum, 1988). In water too shallow for canoes, wild rice was sometimes tied in bundles for later harvesting. When the wild rice was mature, mats could be spread between the rows on the water. The grains could then be knocked onto the mats for collection (Jenks, 1900; Vennum, 1988). According to John Henry McMillen, an Ojibwe elder and expert on wild rice from the Fond du Lac Reservation (personal communication, 2000), Ojibwe elders recall harvesting rice during dry years in water too shallow for canoes by walking in the lake and knocking the wild rice into a basket.

A different method is currently used for wild rice gathering. The only way to legally gather wild rice is to knock the grain from loose panicles into a canoe with two sticks. By law, the binding of wild rice is no longer allowed nor is cutting off the heads.

After collection, wild rice grains had to be dried. Green wild rice grains were scattered on skins or birch bark in the sun to dry. Occasionally the grains were stirred to allow even drying (Jenks, 1900; Densmore, 1928; Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988). Properly dried wild rice could be stored up to several weeks before parching (Dore, 1969; Vennum, 1988).

Parching or roasting of the grains was done to preserve them and to aid in the removal of the hulls. Parching of wild rice was done by heating the wild rice in a container over a fire and stirring the mass to keep it from burning (Jenks, 1900; Densmore, 1928; Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988). Parching involved keeping the fire regulated and required considerable skill to prevent scorching (Densmore, 1928; Vennum, 1988). Parching destroyed the germ, preventing the wild rice grain from sprouting (Vennum, 1988). It also imparted a flavor into the wild rice (Densmore, 1928; Vennum, 1988).

Before the access of metal kettles, wild rice was parched in several different ways. According to Vennum (1988), the Illinois Potawatomi roasted wild rice on hot, flat rocks. Another way to parch wild rice was in pits lined with stones heated by a fire in the depression (Vennum, 1988). Kegg (in Vennum, 1988) relates the use of mats woven of scouring rush (*Equisetum hyemale*) for the parching of wild rice.

According to Kegg (in Vennum, 1988), when no metal kettles were available people of the Mille Lacs Reservation resorted to the older method of using tightly woven fire resistant scouring rush mats propped over a fire to parch wild rice. Vennum (1988, p. 118) also reports the following, "Lips (a German anthropologist) saw kettle roasting as a fairly recent innovation, pointing out that the oldest sources, such as Marquette and Lalemant, omit all mention of parching rice in containers, describing only fire drying. Although there is evidence that some Algonquian tribes made pottery, she dismissed the possibility that stoneware might have been used. The recent testimony of older Ojibway lends credence to Lips's assumption." Vennum (1988) is referring to Kegg's recollection of the Ojibway using scouring rush in the parching of wild rice. Dore (1969) reports that a large basket or bowl was placed over an open fire to parch wild rice. Once iron kettles became available, parching was done almost exclusively in pots (Jenks, 1900; Taube, 1951; Vennum, 1988).

Wild rice could also be dried and cured at the same time by placing it on a scaffold over a small fire (Jenks, 1900; Densmore, 1928; Vennum, 1988). For drying wild rice, the scaffold was a pole frame with cross-poles covered with slabs of cedar (Jenks, 1900; Taube, 1951; Vennum, 1988). Mats of woven cedar or basswood bark, layers marsh grass, small willows (Jenks, 1900; Vennum, 1988), or layers of hay were placed on the cross-poles to prevent the wild rice from falling to the ground (Densmore, 1928; Vennum, 1988). To facilitate drying, a wall of green cedar branches was sometimes created to enclose the scaffold at its base, which caused the smoke and heat to rise through the wild rice (Vennum, 1988). The wild rice was

turned with paddles or shaken occasionally to speed up the drying process (Vennum, 1988). Wild rice that is cured using this method is called "hard rice" (Densmore, 1928).

According to Densmore (1928), hard rice could be kept indefinitely and used for seed. Hard rice is also darker in color than parched rice and requires longer to cook (Densmore, 1928). Jenks (1900), Taube (1951), and Saunders (1976) report that wild rice was processed for use by sun drying alone without the aid of either smoke drying or parching. J.H. McMillen (personal communication, 2000) also reported that Ojibwe elders had recounted processing wild rice using only the sun drying method. J.H. McMillen informed me that according to an Ojibwe elder, wild rice was sometimes stir dried in a basket by adding hot rocks (J.H. McMillen personal communication, 2000).

After parching, fire/smoke drying, sun drying, or other means of drying, the chaff needed to be removed from the grain. This was done by digging a hole approximately 30 cm deep and 50 cm in diameter and lining it with hide, (Jenks, 1900; Densmore, 1928; Vennum, 1988), clay, or bark (Jenks, 1900; Vennum, 1988). The rice was then placed in the ricing jig and stomped with the feet to remove the hulls (Jenks, 1900; Densmore, 1928; Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988). Instead of lining the jig, the rice was sometimes place in a leather bag and then put in the jig to be stomped (Vennum, 1988). To aid the person treading on the wild rice, a support pole was placed on either side of the ricing jig with one end tied about 1.2 m (4 ft) above the ground; the other end rested on the

ground. The poles provided a place for the person to lean on while treading lightly on the wild rice (Jenks, 1900; Densmore, 1928; Taube, 1951; Vennum, 1988). Treading on the wild rice is referred to as "dancing the rice" or "jigging" (Taube, 1951; Vennum, 1988). J.H. McMillen (personal communication, 2000) told the author that a stump hollowed out by burning was used as a ricing jig. The stump was used for several years and could be transported from one processing site to another.

Hulling could also be done using the mortar and pestle method, that is, by pounding the wild rice in a wooden container in the ground with a wooden pole (Jenks, 1900; Densmore, 1928; Taube, 1951; Vennum, 1988). Jenks (1900) and Taube (1951) report that the simplest way of removing the hull was by rubbing the grains between the fingers. He infers, however, that this method was only for small quantities of wild rice. According to Vennum (1988), the Ojibway used this method, or just shook the hulls off. Another method to remove the husk was to pound the wild rice in a bag with a stick (Jenks, 1900; Taube, 1951).

Vennum (1988) relates an instance of in which a fresh (green) deerskin was placed over coals and staked to the ground. The wild rice was then placed on the skin and trodden by a boy (Jenks, 1900; Vennum, 1988). Two other methods of hulling reported by Vennum (1988) include rolling the wild rice with a log like a rolling pin and threshing rice in ditches before curing. Jenks (1900) describes a method of hulling in which a blanket or skin was laid out on the ground and an approximately 3 m high retaining wall was built on three sides. The wild rice was laid on the skin and a person would flail the grain from the open side. The walls kept

the grains contained during thrashing. Another method of removing the husk described by Jenks (1900) was to wait until the dried wild rice was to be eaten and then to pound it into a mass. The mass was then placed into a vessel of water. The lighter hulls, which floated, could be skimmed off the surface of the water after the heavier grains sank to the bottom of the vessel. Sometimes the chaff that was removed during hulling was collected and cooked and eaten much like wild rice (Densmore, 1928; Vennum, 1988).

Following removal of the wild rice from the ricing jig, winnowing was done to remove the loosened chaff from the grain. This was done by throwing the wild rice into the air from bark trays and letting the wind blow the chaff away while the grains fell onto a blanket (Jenks, 1900; Densmore, 1928; Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988).

Completely processed wild rice could then be eaten or stored. Usually wild rice was placed in skin (Jenks, 1900; Densmore, 1928; Vennum, 1988) or bark containers and buried (Jenks, 1900; Taube, 1951; Vennum, 1988). According to J.H. McMillen (personal communication, 2000), wild rice was often buried in baskets.

Traditional Wild Rice Cooking

Traditionally, wild rice was prepared by boiling in water (Jenks, 1900; Taube, 1951; Vennum, 1988) or broth in bark pails and suspended above a fire for cooking prior to the acquisition of metal kettles (Vennum, 1988). The processed wild rice was washed several times prior to cooking. Washing the wild rice removed any dirt

and dust that had accumulated during storage. Washing also floated off bits of chaff that remained from parching (Jenks, 1900; Vennum, 1988). The wild rice was then simmered with water or broth until it absorbed the moisture. The consistency of the final product was determined by the amount of liquid to grain, cooking time, type of processing, and age of wild rice. Overnight soaking might be needed for completely processed or old wild rice (Vennum, 1988). According to Jenks (1900) and Vennum (1988), the most common wild rice dish was a combination of wild rice with other ingredients in a stew. The other ingredients could be almost any meat, fish, or vegetables. Traditionally, the only seasonings used in wild rice dishes were animal fat, berries, and maple sugar. Roasting wild rice was the only other way it could be cooked other than boiling. The wild rice was placed in a pot and cooked over a slow fire. When done the wild rice kernel burst, much like popcorn, revealing the white mealy center (Vennum, 1988; J.H. McMillen, personal communication, 2000).

Although most wild rice was cooked and eaten after being fully processed, the Ojibway would sometimes collect green wild rice for consumption, which they considered a treat (Jenks, 1900; Vennum, 1988; J.H. McMillen, personal communication, 2000). Freshly harvested green wild rice can be cooked in as little as 10 minutes or even by simply pouring boiling water over it (Vennum, 1988; J.H. McMillen, personal communication, 2000).

WILD RICE USE BY NATIVE AMERICANS

Ethnographic accounts (Jenks, 1900; Densmore, 1928; Carlson, 1934; Berde, 1980) indicate that wild rice (*Zizania aquatica*) has been utilized by Native Americans for subsistence for many centuries. Indirect evidence, such as the location of archaeological sites near contemporary wild rice lakes and the presence of ricing jigs, has been documented for several archaeological sites (Johnson, 1969a; 1969b). However, direct archaeological evidence (such as the presence of wild rice grains in archaeological context) that indicates the prehistoric use of wild rice is less abundant.

In Minnesota, direct (charred wild rice grains) and/or indirect (ricing jigs) archaeological evidence for the prehistoric use of wild rice has been found at the Aquipaguetin Island, Cooper, Lower Rice Lake, Mitchell Dam, Nett Lake, Petaga Point, Scott, and Upper Rice Lake sites, which are all in the Mississippi Headwaters region (Johnson, 1969b). Gibbon (1976) reports the presence of nine ricing jigs at the Old Shakopee Bridge site also in the Mississippi Headwaters region. A wild rice grain was observed during excavation of the Old Shakopee Bridge site; unfortunately the grain was lost and its presence cannot be substantiated (Gibbon, 1976).

Peters and Motivans (1984) reported the presence of a large rice processing site (Big Rice Site 21-SL 163) on the north shore of Big Rice Lake near Virginia, Minnesota. Thirty-one ricing jigs and several grains of wild rice were found at the site. Pottery associated with the site includes over 50,000 sherds of Laurel, Blackduck, Sandy Lake, and Selkirk ceramics. This suggests that the pottery was instrumental in the processing of wild rice (Peters and Motivans, 1984). In a study of

flotation samples from the Big Rice site, Valppu (1989) identified wild rice seeds from several of the samples as well as other floral material. The wild rice grains are associated with Laurel ceramics and ricing jigs (Valppu, 1989). Based on a date from a Laurel feature, this association occurred at $1,670 \pm 45$ yr B.P. (Rapp, Allert, and Peters, 1990). Three of four other dates on wild rice grains from the Big Rice site indicate the association of wild rice with Laurel ceramics. The four dates on wild rice grains from the Big Rice site are $1,910 \pm 100$ yr B.P., $2,040 \pm 100$ yr B.P., $2,072 \pm 90$ yr B.P., and 600 ± 60 yr B.P. (Valppu and Rapp, 2000).

A prehistoric archaeological site is located on Shannon Lake. During a preliminary survey of this site, lithic materials, pot sherds, and a ricing jig were found. However, nothing was recovered that specifically dated the site. The pot sherds recovered indicate that the site is of the Woodland Period (G.R. Peters, personal communication; 1987).

Other indirect evidence for the *potential* use of wild rice is the presence of large quantities of grass pollen in lake sediment cores. Wild rice (*Zizania aquatica*) is a grass (Gramineae). Wild rice has a monoporate (single pore) pollen grain (Fig. 18) approximately $32\text{--}36\text{ }\mu\text{m}$ in diameter according to the pollen key by McAndrews, Berti, and Norris (1973). Wild rice pollen is similar in size and surface sculpturing to most other grass pollen and cannot be identified to species with absolute certainty.



Figure 18. Wild rice pollen grain approximately 34 μm in diameter.

McAndrews (1969) measured 100 wild rice pollen grains from two reference slides. Ninety-six of the 100 wild rice pollen grains fell within the range of 25-32 μm , with a peak at 29 μm . McAndrews (1969) used the wild rice grain size frequency in addition to percentage data to establish the expansion of wild rice in Rice Lake, Becker County, Minnesota. In most palynological investigations, the presence of wild rice in the pollen record is based primarily on abundance rather than on the size of grass pollen grains. Based on modern and fossil pollen deposition, a pollen percentage value of 40% of the pollen sum is assumed to indicate the presence of a major stand of wild rice in a lake (Yourd, 1988).

The oldest Gramineae rise of 40% or greater, which indicates the presence of a substantial stand of wild rice, is from the Wolf Creek pollen profile in east central Minnesota (Fig. 19). The Gramineae rise dates between 10,000 and 9,000 yr B.P. (Birks, 1976). Wild rice grains were also recovered from the same section of the core as the Gramineae rise (Birks, 1976). The combination of wild rice grains and a large Gramineae pollen rise supports the assumption that Gramineae pollen present in quantities of 40% or greater indicates the presence of a substantial wild rice bed on a lake.

Based on palynological data, a Gramineae rise has been attributed to the expansion of *Zizania aquatica* at Rossburg Bog between 4,000 and 6,000 yr B.P. (Wright and Watts, 1969) and at 5,000 years ago at Cedar Bog Lake (Cushing, 1963). At Pogonia Bog Pond, two Gramineae maxima divided by a Gramineae minima occur (Swain, 1978). The first maxima occurs at approximately 5000 years ago, while the

second begins about 2,200 years ago. At the base of the core from Lake Onamia, which dates to approximately 3,000 yr B.P., Gramineae pollen values had already reached almost 90% (McAndrews unpublished in Yourd, 1988). Between 5,000 and 4,000 yr B.P., there is a Gramineae maxima at Tamarack Swamp; another Gramineae maxima occurs between 3,000 yr B.P. and 2,000 yr B.P. (Swain, 1978). The Gramineae rise begins about 2,300 years ago at Wolsfeld Lake (Grimm, 1981) and about 2100 yr B.P. at Ogechie (McAndrews unpublished in Yourd, 1988).

McAndrews (1969) completed a palynological investigation of a core from Rice Lake, Becker County, Minnesota, near the Mitchell Dam site. His investigation suggests that wild rice was present over most of the lake approximately 2,000 years ago. At Rice Lake, Ontario, near the McIntyre site, McAndrews (1984) has shown that wild rice was probably in harvestable quantities 3,700 years ago during the Late Archaic occupation of the site.

By 2,100 yr B.P., Gramineae pollen values at Marquette Pond reached 40% (Yourd, 1988). Short lived Gramineae maxima occur at approximately 1,500 yr B.P. at Bog D Pond (McAndrews, 1966) and at 1,100 yr B.P. at Ondris Pond (Jacobson 1975; 1979). Figure 19 shows the location of pollen sites in Minnesota with a Gramineae rise attributed to the expansion of wild rice.

It must be noted that the evidence for the presence of wild rice based Gramineae pollen profiles only provides indirect evidence for the *potential* use of wild rice by Native Americans. Establishing the past presence of wild rice in a lake only determines availability *not* utilization.

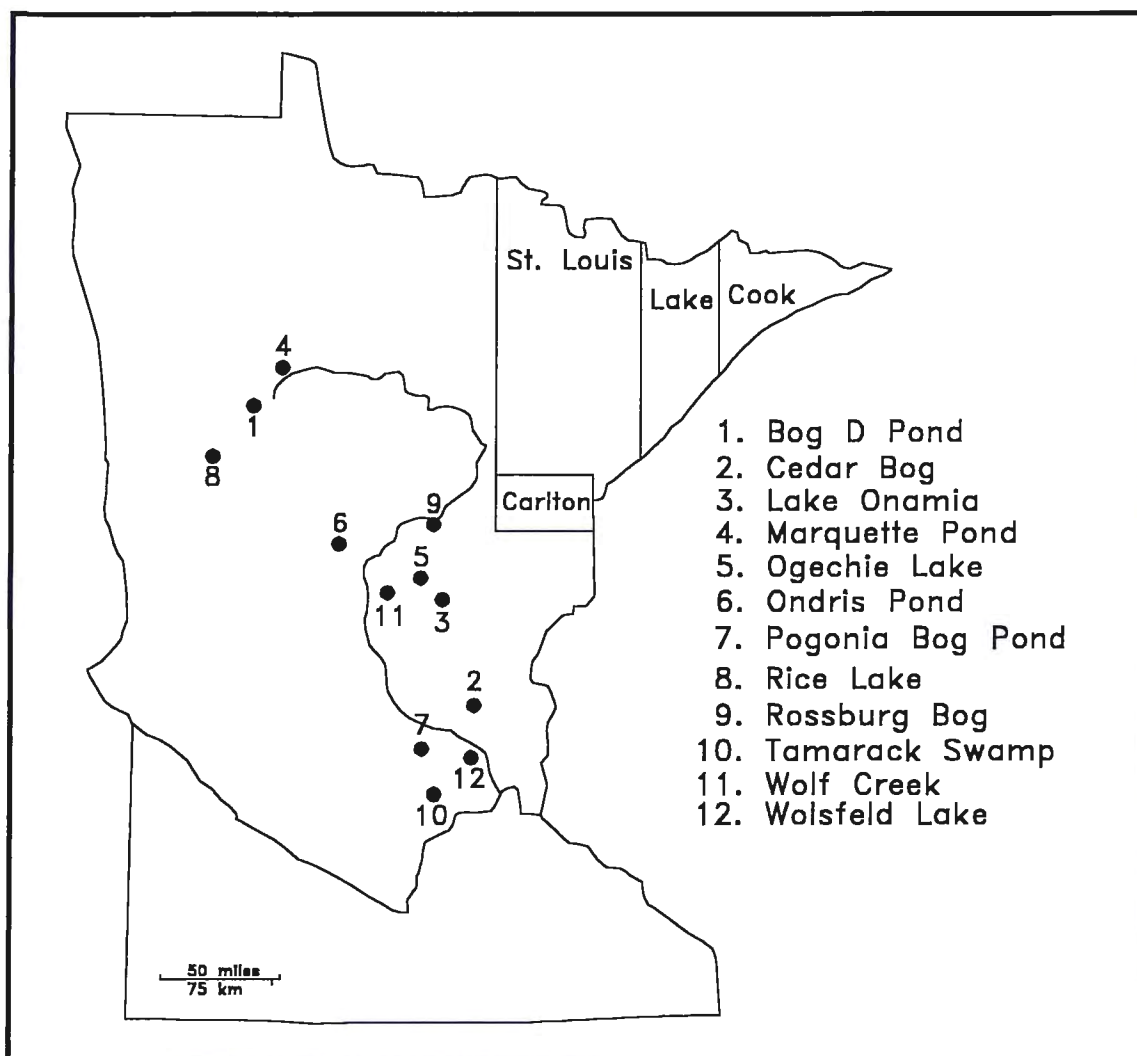


Figure 19. Location map of pollen sites with a Gramineae pollen rise attributed to the expansion of wild rice.

V. DATA COLLECTION

THE STUDY AREA

The study area is located in the Arrowhead region of northeast Minnesota, which is defined here as Carlton, St. Louis, Lake, and Cook counties. The 19 lakes investigated in the study area are Big Rice, Cloquet, Cramer, Devil Track, Dumbbell, East Bearskin, Elbow, Gegoka, Greenwood, Little Rice, Moose, Musquash, Northern Light, Perch, Rice Portage, Round Island, Shannon, Swamper, and Wild Rice Lake Reservoir (Fig. 20). The county, UTM coordinates, surface area of lake (hectares), and lake type (wild rice lake or not a wild rice lake) for each lake is given in Table 1. All of the lakes are in UTM Zone 15 and locations are based on North American Datum 1983.

Big Rice and Little Rice lakes are in the Big Rice Outwash Plain. Originally, the area was pine forest. Seventy to eighty percent is now covered by a mixed stand of aspen, spruce, balsam fir, and jack pine (University of Minnesota Experiment Station, 1971).

Shannon Lake is in the sandy Prairie River Plain. Originally, the forest consisted of pine on the sand plain and conifer on the bogs. The main taxa currently found in the area are aspen, white birch, and various pines (University of Minnesota, Agricultural Experiment Station, 1971).

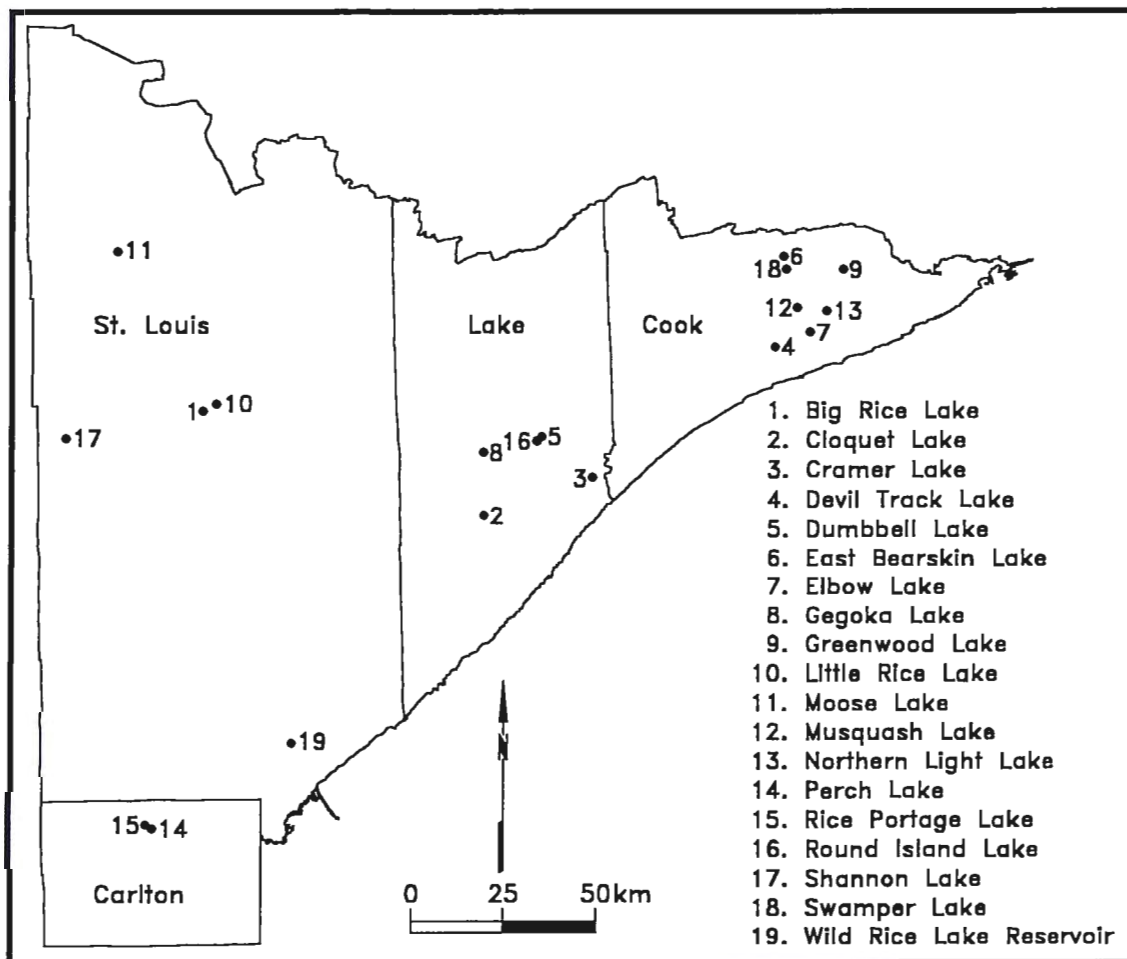


Figure 20. Location map of study lakes.

TABLE 1. LAKE LOCATIONS, SIZE, AND TYPE.					
Lake	County	XUTM	YUTM	Area (ha)	Type
Big Rice Lake	St. Louis	538330	5282323	838.87	Rice
Cloquet Lake	Lake	613991	5254560	75.30	Non Rice
Cramer Lake	Lake	643298	5264645	27.94	Rice
Devil Track Lake	Cook	692697	5299551	758.30	Non Rice
Dumbbell Lake	Lake	629660	5275449	192.71	Rice
East Bearskin Lake	Cook	694988	5323688	260.32	Non Rice
Elbow Lake	Cook	702107	5303557	168.02	Rice
Gegoka Lake	Lake	613890	5271296	70.45	Rice
Greenwood Lake	Cook	710969	5320190	841.30	Non Rice
Little Rice Lake	St. Louis	542069	5284272	107.69	Rice
Moose Lake	St. Louis	515662	5325166	381.38	Rice
Musquash Lake	Cook	698534	5310047	33.20	Non Rice
Northern Light Lake	Cook	706538	5309141	179.35	Rice
Perch Lake	Carlton	525071	5170353	322.27	Rice
Rice Portage Lake	Carlton	523373	5171387	336.84	Rice
Round Island Lake	Lake	628337	5274352	23.48	Rice
Shannon Lake	St. Louis	502074	5275043	54.66	Rice
Swamper Lake	Cook	695731	5320283	21.05	Non Rice
Wild Rice Lake Reservoir	St. Louis	562272	5193200	663.56	Rice

Cloquet Lake, Cramer Lake, Round Island Lake, and most of Devil Track Lake are in the northeastern portion of the Highland Moraine. The original vegetation was predominately white pine, red pine, balsam fir, and spruce. Currently, the vegetation is composed mainly of trembling aspen, balsam fir, and birch (University of Minnesota, Agricultural Experiment Station, 1981). Most of Perch Lake, Rice Portage Lake, and Wild Rice Lake Reservoir are located in the southwest portion of the Highland Moraine. The original forest in the southwest part of the Highland Moraine was mostly white spruce, balsam fir, red pine, and white pine, with locally occurring stands of northern hardwoods. Aspen, spruce, fir, and some hardwoods currently make up most of the vegetation (University of Minnesota, Agricultural Experiment Station, 1977). The southwest part of Perch Lake is in the Automba Drumlin Area. The original forest was principally red and white pine, with tamarack and black spruce in most peat bogs. Aspen, hardwoods, spruce, and fir are the main taxa currently found in the area (University of Minnesota, Agricultural Experiment Station, 1977).

Dumbbell Lake, Elbow Lake, Gegoka Lake, and the northwest end of Devil Track Lake are in the Vermillion Moraine. Originally, the vegetation was white and red pine, balsam fir, and spruce. The current forest is composed mainly of trembling aspen, balsam fir, birch, and some jack and red pine (University of Minnesota, Agricultural Experiment Station, 1981).

East Bearskin Lake, Greenwood Lake, Musquash Lake, Northern Light Lake, Swamper Lake, and the north end of Moose Lake are in the Tower-Ely Glacial Drift and Bedrock Complex. Red pine, white pine, balsam fir, and spruce dominated the original forest. The current forest consists mainly of trembling aspen, red pine, birch, and spruce. The majority of Moose Lake lies within the Agassiz Lacustrine Plain. The original vegetation in the Agassiz Lacustrine Plain was jack pine on the sandy soils and white pine, red pine, white spruce, and balsam fir on the clayey soils, and black spruce and tamarack on the organic soils. Currently, forest cover on the organic soils is dominantly black spruce, tamarack, and alder. On mineral soils, the current vegetation consists mainly of trembling aspen, balsam fir, and some jack pine (University of Minnesota, Agricultural Experiment Station, 1981).

METHODS

Coring and Surface Sediment Sampling

Sediment samples for this investigation were obtained using three different types of samplers. Long cores (1 m or greater) were retrieved using a modified Livingstone piston sampler 5 cm in diameter and 100 cm long (Livingstone, 1955; Vallentyne, 1955; Wright, 1967). Short cores (50 cm or less) were recovered from the lake bottoms using a dropcorer manufactured by the Wildco Wildlife Supply Company. Sediment samples of the uppermost lake sediment (approximately 1 cm) were obtained using a Hongve surface sediment sampler (Wright, 1980).

At Cloquet Lake, Gegoka Lake, East Bearskin Lake, Little Rice Lake, Shannon Lake, and Wild Rice Lake Reservoir, the 1 m sections of the long cores were extruded, described, and wrapped in Saran wrap and aluminum foil in the field. They were transported to the Archaeometry Laboratory and stored in a cooler at 4°C until analysis could be undertaken. At Big Rice Lake, core sections were extruded into clean plastic PVC pipe, labeled, and returned to the Archaeometry Laboratory at the University of Minnesota, Duluth. The core sections were transported and stored in an upright position to prevent mixing of the sediment. Because of the viscous nature of some of the lake sediment, the core sections were frozen in the PVC pipe and then extruded. The core sections were then cut into 1-cm lengths, placed in labeled sterile bags, and frozen until analysis could be undertaken.

Long cores were recovered from Cloquet, Gegoka, and Shannon lakes using a portable coring platform (Huber and Dorland, 1990). At Big Rice Lake, East

Bearskin Lake, Little Rice Lake, and Wild Rice Lake Reservoir, long cores were retrieved from the frozen lake surface.

Short cores were recovered from Devil Track Lake, Elbow Lake, Greenwood Lake, Musquash Lake, Northern Light Lake, and Swamper Lake using a Wildco dropcorer. The Wildco dropcorer has a brass core tube with a flap valve, a tapered nosepiece, and an option to use a plastic core liner and eggshell core catcher. Core liners and a core catcher were used to obtain the lake sediment cores. After the drop corer was retrieved from the lake bottom, the core liner containing the core was removed and core caps were placed on the top and bottom liner tube. Masking tape was then wrapped around the cap and the tube to prevent the core caps from coming off. The cores were returned to the laboratory in an upright position and stored in a cooler at 4° C. Excess water was later pipetted from the core tubes. The cores were then extruded from the plastic core tubes, wrapped in Saran wrap and aluminum foil, and then returned to the cooler until analysis could be undertaken.

At Devil Track, Elbow Lake, Greenwood, Musquash, and Northern Light lakes, coring was carried out from a boat or canoe. The Swamper Lake short core was obtained from the frozen lake surface.

Surface sediment samples were collected from Big Rice Lake, Cramer Lake, Dumbbell Lake, Gegoka Lake, Little Rice Lake, Moose Lake, Perch Lake, Rice Portage Lake, Round Island Lake, and Shannon Lake. The surface sediments (approximately 1 cm) of the Hongve samples were transferred to ziplock bags. The Hongve samples were returned to the laboratory and stored in a cooler at 4° C.

A canoe was used to obtain the Hongve samples at Big Rice, Cramer, Dumbbell, Gegoka, Little Rice, Perch, Rice Portage, Round Island, and Shannon lakes. At Moose Lake, the Hongve sample was collected using a Beaver airplane equipped with pontoons.

Pollen Analytical Methods

One cc subsamples were removed from the 1-cm length sections for the Big Rice Lake Core 1 and 1-cc plugs of sediment were removed from the Shannon Lake Core 3, Cloquet Lake, Gegoka Lake Core 1, East Bearskin Lake, and Wild Rice Lake Reservoir long cores at 5-cm intervals for pollen and algae analysis. For all of the short cores and long cores used only for surface sediment samples, 1-cc plugs of sediment were removed from the top one cm of the core. Approximately 1 g of wet sediment was analyzed from the Hongve surface sediment samples. One *Eucalyptus* tablet was added to each sample to allow calculation of pollen concentrations (Maher, 1972) for all long and short core samples, but not the Hongve samples. Pollen samples were treated with a modified Faegri and Iverson (1975) technique (KOH, HCl, HF washes, and acetolysis), sieved through seven μm Nitex screens (Cwynar, Burden, and McAndrews, 1979), stained with safranin, and stored in silicone oil.

Loss-On-Ignition of Organic Carbon and Carbonate

Each lake core or sediment sample was systematically sampled at the same intervals as pollen for loss-on-ignition (LOI) analysis to determine the relative proportions of organic and carbonate carbon. Initial wet samples from the cores were approximately 1-cc. LOI analysis followed the method described by Dean (1974). The samples were dried at 105° C to determine dry weight. Percent LOI was determined by combustion at 550° C for one hour for organic carbon and at 1000° C for one hour for carbonate carbon.

Palynomorph Identification and Counting Techniques

A minimum of 400 grains of trees, shrubs, and herbs (including vascular cryptogams) was identified for each sample. Indeterminable and unknown pollen grains, aquatic pollen, moss spores, nonsiliceous algae, fungal spores, pre-Quaternary fossils, and *Eucalyptus* spike grains were counted outside the pollen sum.

Pollen and spores were identified using the keys in Maloney (1961), Kapp (1969), and McAndrews, Berti, and Norris (1973), and by comparison to the pollen reference collection at the Archaeometry Laboratory, University of Minnesota, Duluth. Algae were identified using the keys in Prescott (1982) and Van Geel (1986).

Identifications were made to the lowest taxonomic level possible. The degree of certainty of identification for some taxa is indicated by the use of “type” and “cf.” The use of “type” indicates that the taxon matches not only that taxon but

others also. An identification preceded by "cf." was uncertain as a result of inadequate reference material, poor preservation, or ill-defined morphology (Watts and Winter, 1966). Indeterminable pollen grains were divided into five categories as proposed by Cushing (1967): broken, concealed, corroded, crumpled, and degraded. Well-preserved pollen grains that were not identified are expressed simply as unknowns.

Pollen Zonation

To delineate pollen and nonsiliceous algae assemblage zones for each lake, constrained single link clustering (CONSLINK), binary division using an information content criterion (SPLITLSQ), binary division using sum-of-squares criterion (SPLITLSQ), and group optimal sum-of-squares partitioning were undertaken following the numerical zonation procedures of Gordon and Birks (1972; 1974) and Birks and Gordon (1985) using the program ZONAT (Birks and Gordon, 1985). In addition to these methods, confidence limits of various taxa (Maher, 1972), the relative percentages of each taxa, and palynomorph concentration were checked for significant differences between samples. The pollen spectra from each lake were also visually compared to pollen zones delineated at other sites in the region.

Wild Rice (*Zizania aquatica*) Pollen Grain Size Frequencies

For comparison of size frequencies between wild rice (*Zizania aquatica*) pollen and fossil grass (Gramineae) pollen in a manner similar to that of McAndrews (1969), 100 wild rice grains were measured in each of seven reference slides. The grains were measured at 420X, the same power routinely used for pollen counting. The pollen grain size frequency was calculated for the 700 wild rice grains and the 90% confidence limits were then determined.

All grass pollen grains identified during pollen counting of the lake surface sediments were also measured at 420X. In addition, grass pollen grains from selected samples from the Big Rice Lake, Gegoka Lake, Shannon Lake, and Wild Rice Lake Reservoir long cores were measured.

Grass pollen grains were measured during routine pollen counting on the Wild Rice Lake Reservoir long core samples and all of the surface sediment samples from Cramer, Dumbbell, Little Rice, Moose, Perch, Rice Portage, and Round Island lakes. Grass pollen grains were also measured during routine pollen counting on surface sediment samples from Core 1, Core 3, and the Hongve sample from Big Rice Lake, Core 1, Core 2, and the Hongve sample from Shannon Lake, and the Hongve samples from Gegoka Lake. For grass pollen grain measurements from previously counted samples, a new pollen slide was made and grass pollen grains equal to the number originally counted were identified and measured. This method was used to determine grass pollen size frequency on the surface samples of the cores from Cloquet, Devil Track, East Bearskin, Elbow, Greenwood, Musquash, Northern Light, and Swamper

lakes and surface sediment and selected samples from Big Rice Lake Core 1, Gegoka Lake Core 1, and Shannon Lake Core 3. Grass pollen grains broken or too crumpled to measure were recorded and included in the grass pollen sum for all samples in which grass pollen measurements were undertaken. For each sample, size frequency was calculated for the measured grass pollen grains.

Ethnographic Analogy

Much of the available information known about the protohistoric use of wild rice by Native Americans comes from ethnographic accounts and accounts recorded by early explorers, fur traders, missionaries, and military personnel. Jenks (1900) produced the first major work on wild rice in "The Wild Rice Gatherers of the Upper Great Lakes." Vennum (1988) compiled much of the known ethnographic information on wild rice in his book "Wild Rice and the Ojibway People," which includes many little known and hard to get sources. The works by Jenks (1900), Vennum (1988), and other authors, as well as interviews with living Native Americans, allows the use of ethnographic analogy in interpretation and speculation on the past use and potential use of wild rice in northeast Minnesota.

Fagan (1994), Gibbon (1984), and others have promoted the use of ethnographic analogy to interpret archaeological data. Kamp (1988) has used ethnographic analogy in many areas of Puebloan life to interpret the archaeological data from the Lizard Man Village site in Arizona. In her attempt to use ethnographic

analogy to interpret archaeological data, Kamp (1988) cautions that one should not rely too heavily on ethnographic analogies because cultures are constantly changing.

In this study, ethnographic information on the use of wild rice by Native Americans is used to stimulate thought and discussion on how wild rice could have been utilized in the past and not leave a signature in the archaeological record. Information provided by a local Native American elder and expert on the traditional use of wild rice by the Ojibwe is also used in this endeavor.

SHANNON LAKE: LONG CORE

Shannon Lake is in sections 34 and 35, T60 N, R21W and sections 2 and 3, T59N, R21W of the Dewey Lake NW 7.5' quadrangle and in section 2, T59N, R21W of the Dewey Lake 7.5' quadrangle, St. Louis County, Minnesota. On 9 September 1989, a 790-cm long Core 3 was retrieved from Shannon Lake at approximately UTM: 502126,5274880, Zone 15 from a depth of 5.33 m.

Only the uppermost 15 cm of the 790-cm long core from Shannon Lake was analyzed for this investigation. Four samples were analyzed for pollen at 5-cm intervals to determine the abundance of Gramineae pollen in a wild rice lake. The lowermost 90 cm of the core has been analyzed for pollen (Huber, in press) and nonsiliceous algae (Huber, 2000).

The pollen diagram from the lowermost 90 cm of the core has been divided into two pollen-assemblage zones. The lowermost zone (Zone SL-1) is comparable to the Compositae-Cyperaceae Assemblage Zone of Cushing (1967) indicating tundra vegetation with occasional stands of spruce or outliers of individual spruce trees, dwarf birch, and willow. Zone SL-2 is comparable to the *Picea-Pinus* Assemblage Zone of Cushing (1967) and is interpreted as representing a conifer-hardwood forest. Absent from the 700-790 cm pollen sequence from Shannon Lake is the *Betula-Picea* Assemblage Zone (Cushing, 1967) that commonly occurs between these two zones in northeast Minnesota (Huber, in press).

The lowermost 90 cm from Shannon Lake Core 3 has been divided into two algae zones. The oldest zone (Zone 1) is dominated by *Tetraedron* (mostly *Tetraedron minimum*), *Scenedesmus*, and *Pediastrum Boryanum*. *Tetraedron* declines from a maximum of 62% in Zone 1 to less than 10% in Zone 2 as *Scenedesmus* and *P. Boryanum* increase. The decline of *Tetraedron* in Zone 2 is associated with the decline in spruce and increase in pine (Huber, 1999).

Stratigraphy

The upper 20 cm of the Shannon Lake core is composed of detrital gyttja.

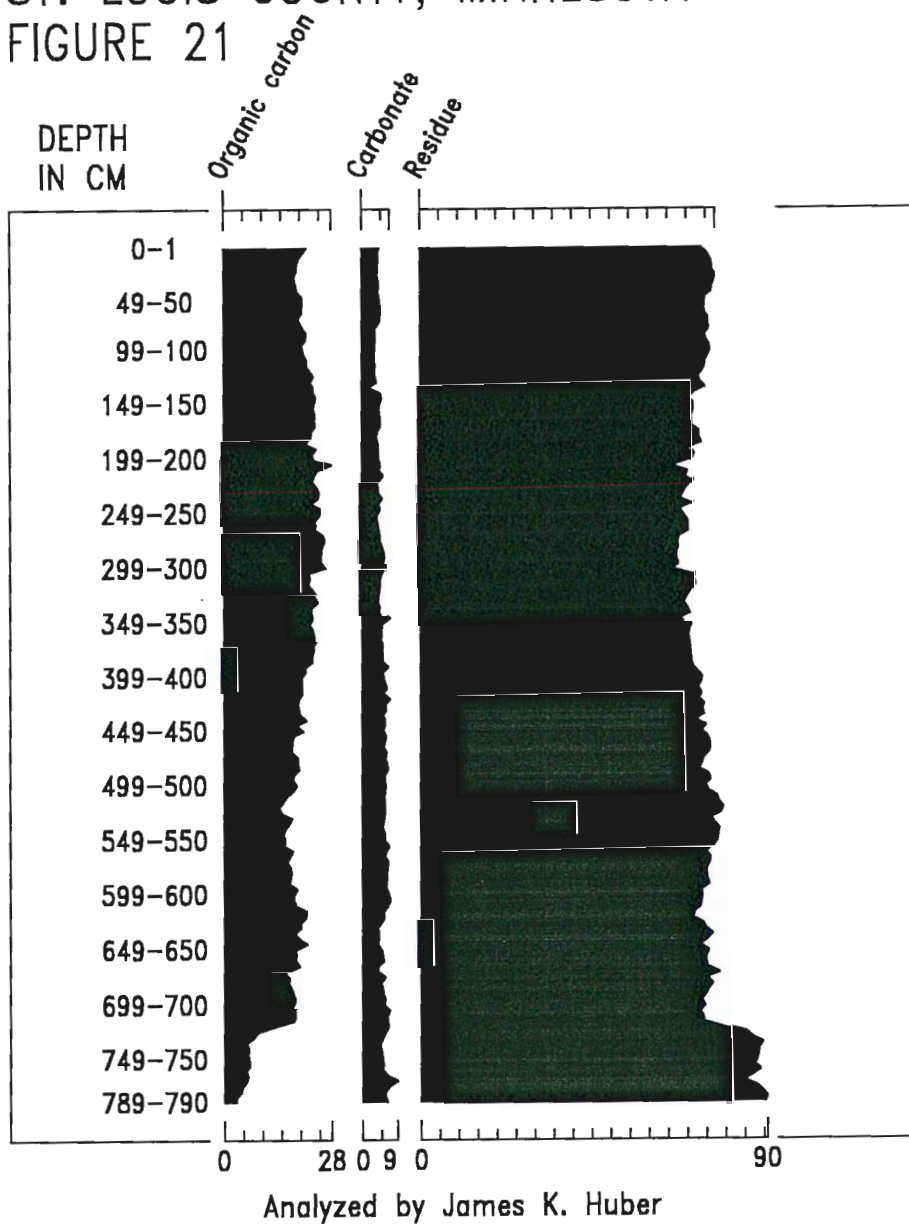
Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon and carbonate content for the entire Shannon Lake core is plotted in Figure 21. An abrupt change in organic carbon content occurs at 720 cm. Carbonate content is low, 4% or less throughout the entire core (Fig. 21).

Pollen Spectra

In the upper four samples examined for this investigation, arboreal pollen values ranged from 86.4% to 90.3% (Plate 1). *Pinus* dominates the pollen spectra with values of 51-57%. *Pinus banksiana/resinosa* and *Pinus strobus* values fluctuate between 19% and 31%; *Pinus* undifferentiated values are 7% or less. Other dominant AP taxa are *Picea* (7-8%), *Betula* (6-12%), *Alnus* (9-11%), and *Quercus* (1-4%).

LOSS-ON-IGNITION PERCENTAGE DIAGRAM
SHANNON LAKE
ST. LOUIS COUNTY, MINNESOTA
FIGURE 21



Gramineae is the most abundant NAP type present with values of 4-7.5% (Plate 1). The second most abundant NAP type is Cyperaceae at approximately 2% throughout the sequence. *Ambrosia*-type values are low, less than 2%. The only aquatic pollen types that occur are *Potamogeton*, *Nuphar*, and *Sparganium*-type with values of less than 1% (Plate 1).

Algae Spectra

Gloeotrichia-type is the most abundant algae with values of <1-9% (Fig. 22) in the upper four samples of Shannon Lake Core 3. Other algae taxa that occur sporadically at 1% or less are: *Scenedesmus*, *Tetraedron*, *Zygnema*-type (spore), *Spirogyra*-type (spore), *Mougeotia* (zygospore), *Pediastrum Boryanum*, *Pediastrum Boryanum* var. *longicorne*, and *Pediastrum duplex*.

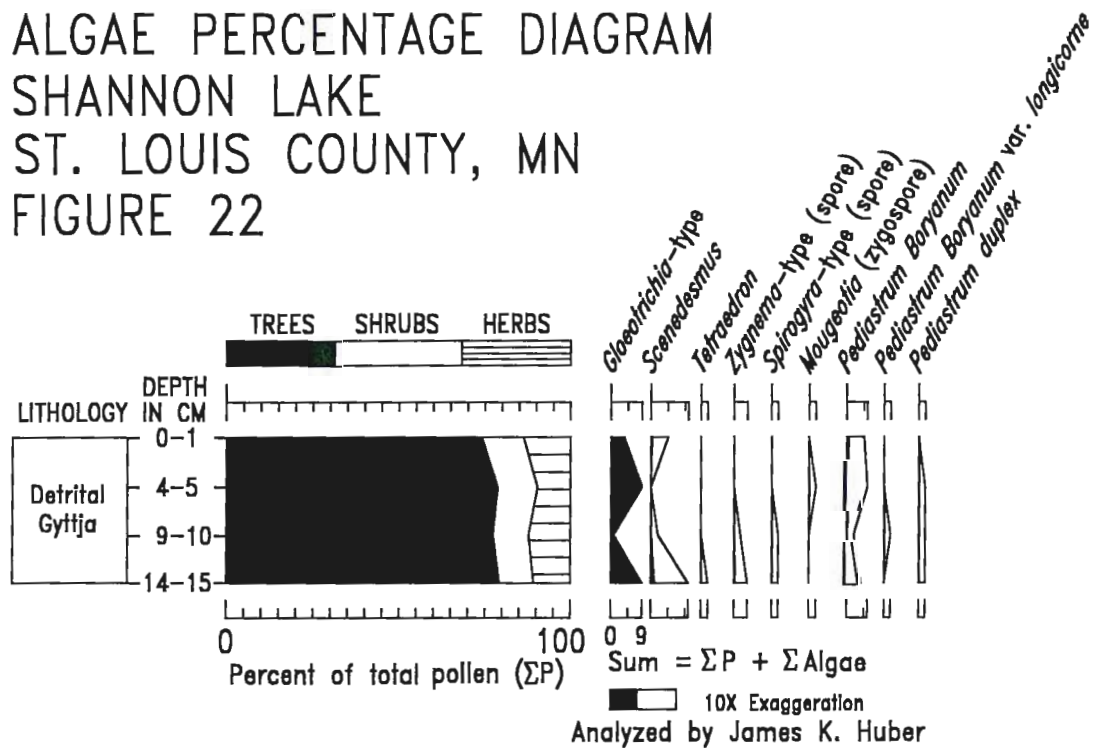
Discussion

The pollen spectra from the upper lake sediments are consistent with the mixed conifer-hardwood forest present in the area today. The *Ambrosia*-type pollen rise commonly found in the midwest associated with deforestation and land clearance by Euro-American settlement (Wright, 1971) is not evident in the pollen spectra. *Ambrosia*-type pollen concentration is relatively stable 1,144 (0-1 cm), 1,977 (4-5 cm), 1,160 (9-10 cm), and 1,589 (14-15 cm) grains/cm³ of wet sediment, and does not show a substantial increase that can be attributed to land deforestation and clearance that occurred in this area around 1890 (Maher, 1977). The lack of a

Ambrosia-type pollen rise may be the result of low Euro-American activity in the immediate vicinity of the lake. The low Gramineae pollen values do not appear to reflect the approximately 10 ha of wild rice that occurs in small stands in bays and shallow areas of Shannon Lake.

Gloeotrichia-type is a blue green (Cyanochloronta), nitrogen fixing algae (Van Geel, Coope, and Van Der Hammen, 1989). The abundance of *Gloeotrichia*-type algae may indicate nutrient poor conditions. *Gloeotrichia* algae which can absorb nitrogen gas directly from the atmosphere (Lee, 1980) and are able to bloom without the competition from other algae. The colonial green algae (Chlorophycophyta) *Scenedesmus* (indicative of elevated nutrient levels), and *Pediastrum Boryanum* (an indicator of lake eutrophication) (Cronberg, 1982) and the spores of *Mougeotia*, *Spirogyra*, and *Zygnema* (indicators of mesotrophic habitats) (Van Geel, 1978) are present in low values and also indicate nutrient poor conditions. *Tetraedron* is a tychoplanktonic genus most commonly found in shallow, nearshore waters in association with macrophytic vegetation (Prescott, 1962) such as wild rice.

ALGAE PERCENTAGE DIAGRAM SHANNON LAKE ST. LOUIS COUNTY, MN FIGURE 22



BIG RICE LAKE: LONG CORE

Big Rice Lake is located in sections 9, 16, and 17, T60N, R17W of the Britt 7.5' quadrangle and sections 2, 3, 9, 10, 11, 14, 15, and 16 T60N, R17W of the Biwabik NW 7.5' quadrangle, St. Louis County, Minnesota. Core site 1 was cored on 31 January 1984 and is located at approximately UTM: 537914,5282524, Zone 15. The depth to the water/sediment interface at Core site 1 was 1 m. A penetration depth of 525 cm was obtained during coring, however pollen is scarce below 270 cm.

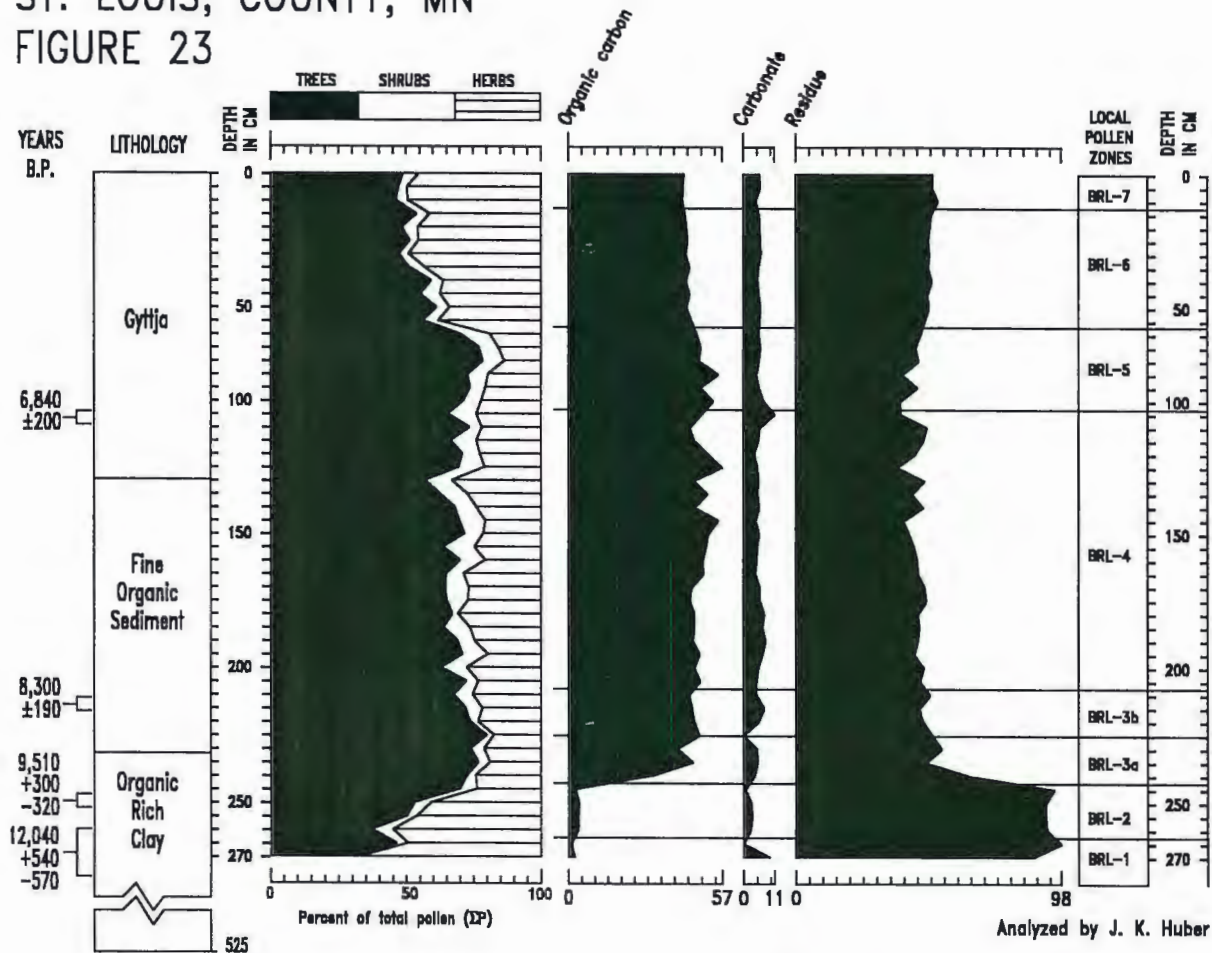
Stratigraphy

The uppermost section of the core was compacted very little, but as the frozen core was cut during sampling, failure to allow for the width of the saw blade reduced this section 15 cm. The bottom level of this section, labeled 85 cm, is actually 100 cm. The core is primarily composed of three sections: the upper section is gyttja; the middle is fine organic sediment; and the lower section is organic rich clay.

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon and carbonate content for the upper 270 cm of the Big Rice Lake core is plotted in Figure 23. Organic carbon content changes abruptly at 240 cm. Carbonate carbon content ranges from less than 1% to 11%, occurring at less than 8% except for peaks at 270 cm and 105 cm. Carbonate occurs at less than 1% at 265 cm, 245 cm, and 225 cm (Fig. 23).

LOSS-ON-IGNITION PERCENTAGE DIAGRAM
BIG RICE LAKE
ST. LOUIS, COUNTY, MN
FIGURE 23



Radiocarbon Dates and Sedimentation Rates

Four sediment samples from the Big Rice Lake core were radiocarbon dated. They are 102-107 cm, $6,840 \pm 200$ yr B.P. (DIC-3319); 207-212 cm, $8,300 \pm 190$ yr B.P. (DIC-3320); 242-247 cm, $9,510 + 300/-320$ yr B.P. (DIC-3321); and 255-272 cm, $12,040 + 540/-570$ yr B.P. (DIC-3322). Estimated sedimentation rates for the core are: 0.10 mm/yr for 12,040-9,510 yr B.P.; 0.29 mm/yr for 9,510-8,300 yr B.P.; 0.72 mm/yr for 8,300-6,840 yr B.P.; and 0.15 mm/yr for 6,840-present. The average estimated accumulation rate for Big Rice Lake sediments is 0.22 mm/yr. A fifth sediment sample submitted for radiocarbon dating of the Gramineae pollen rise was lost by the radiocarbon laboratory. No more material from the core was available for this interval, therefore no radiocarbon date for the Gramineae pollen rise has been obtained.

Pollen Zone BRL-1

In Zone BRL-1, nonarboreal pollen (NAP) values are greater than 40%. Cyperaceae (27-52%), *Artemisia* (8%), and *Ambrosia*-type (3-7%) are the prominent NAP types found at Big Rice Lake. Gramineae values are less than 3%. *Picea* (16%) is the dominant arboreal pollen (AP) type; *Betula* (6-21%) is also important (Plate 2). A large interval ^{14}C date for most of Zone BRL-1 (255-272 cm) is $12,040 + 540/-570$ yr B.P.

Pollen Zone BRL-2

Cyperaceae continues to be the dominant NAP type, but declines from 32% to 10% in Zone 2. *Artemisia* (7-10%), and *Ambrosia*-type (1-5%) are still prominent. Gramineae values are between 1% and 3%. *Betula* (11-26%) and *Picea* (12-27%) are the most abundant AP types and *Salix* (2-5%) is more common than in Zone BRL-1 (Plate 2). The top of this zone is dated at approximately 9,500 yr B.P.

Pollen Zone BRL-3

Two subzones are recognized in Zone BRL-3. Subzone BRL-3B is delineated by a maxima of *Abies* (2-6%). This zone is characterized by high percentages of *Picea* (13-33%) and *Pinus*, mostly *Pinus banksiana*/*P. resinosa*, (18-34%), with *Picea* reaching its greatest abundance in subzone BRL-3A. The deciduous trees, *Quercus*, *Ulmus*, and *Fraxinus*, all have maxima in this zone. *Salix* is still an important minor component, but is declining. *Alnus* values begin to increase in the upper part of this zone. Cyperaceae continues to decline from 10% to 4% in Zone BRL-3 and *Artemisia* (2-7%), and *Ambrosia*-type (1-2%) are still prominent. Gramineae values increase in the upper part of the zone. Chenopodiaceae/Amaranthaceae is present at 1% to 2% (Plate 2). This zone is dated from approximately 9,500-8,300 yr B.P.

Pollen Zone BRL-4

Zone BRL-4 covers a period from approximately 8,300-6,800 yr B.P. and is dominated by *Pinus*. Most of the identifiable *Pinus* grains in this zone are *Pinus*

banksiana/P. resinosa-type. Many of the pine grains are represented by wings of broken grains and are not identified below the level of genus. After *Pinus*, *Betula* (6-12%), and *Alnus* (4-8%) are the most dominant AP types. *Picea* and *Abies* decrease to less than 1.5%. *Quercus* and *Ulmus* continue throughout Zone BRL-4 at slightly lower values than in Zone BRL-3. Gramineae, *Ambrosia*-type, and Chenopodiaceae/Amaranthaceae pollen all increase in Zone BRL-4 while *Artemisia* remains fairly constant at about 5% (Plate 2).

Pollen Zone BRL-5

Quercus reaches its maximum (8%) and *Ulmus* increases slightly in Zone BRL-5. There is also a shift from *Pinus banksiana/P. resinosa* to *Pinus strobus* at approximately 6,800 yr B.P. *Betula*, *Alnus*, and Gramineae values remain stable throughout this zone as Chenopodiaceae/Amaranthaceae *Artemisia*, and *Ambrosia*-type decrease (Plate 2) decrease.

Pollen Zone BRL-6

Zone BRL-6 is characterized by a dramatic increase in Gramineae pollen. Gramineae pollen increases abruptly from 8% at the top of Zone BRL-5 to 35% at the bottom of Zone BRL-6 (Plate 2). There is no radiocarbon date on the increase in Gramineae from the core. Based on sediment accumulation rates, the Gramineae rise is estimated to date at 3,670 years B.P. Chenopodiaceae/Amaranthaceae, *Artemisia*, and *Ambrosia*-type values are all low in Zone BRL-6 (Plate 2). In Zone BRL-6,

Pinus values decrease in relation to the large increase in Gramineae. *Quercus* values decline after a maxima in Zone BRL-5, *Ulmus* values also decrease. *Betula* and *Alnus* values remain stable. *Picea* increases slightly in this zone (Plate 2).

Pollen Zone BRL-7

Zone BRL-7 is marked by a small increase in *Ambrosia*-type (Plate 2) that may be the result of deforestation in the area and the advent of pioneer settlement about 1890. Percentage values of *Ambrosia*-type pollen in this zone are almost twice as great without Gramineae as part of the pollen sum. *Ambrosia* concentration values jump from approximately 3,000 grains/cm³ of wet sediment grains in Zone BRL-6 to 20,000 grains/cm³ of wet sediment in Zone BRL-7.

Algae Zone BRL-1

In pollen zone BRL-1, *Pediastrum Boryanum* is the dominant algae found in this zone, followed by *Pediastrum integrum* and *Pediastrum simplex* (Plate 3). *Scenedesmus* occurs at less than 5%. Total algae concentration (4031 coenobia/cm³) in this zone is low, which according to Birks (1976) indicates low lake productivity. Low productivity is also indicated by the lack of organic material in the sediments associated with this zone. *Pediastrum integrum* and *Pediastrum simplex* were found by Birks (1976) in association with pioneer macrophytes at Wolf Creek in central Minnesota.

Algae Zone BRL-2

In zone BRL-2, *Scenedesmus* percentages and concentrations increase. *Pediastrum Boryanum*, *Pediastrum integrum*, *Pediastrum muticum*, *Pediastrum simplex*, and *Pediastrum Kawraiski* all have maxima in this zone (Plate 3). The increase and decrease in total *Pediastrum* in this zone was also observed in a similar zone described by Wright and Watts (1969) for Anderson Lake, Pine County, Minnesota.

Scenedesmus and/or *Pediastrum* maxima associated with the late glacial spruce zone (Crisman, 1978; Huber and Overstreet, 1990) have been documented at sites in Minnesota and Wisconsin.

Algae Zone BRL-3

Scenedesmus increases drastically in this zone from 13.8% in Zone BRL-2 to as high as 60.1% in Zone BRL-3 (Plate 3). *Scenedesmus* concentrations increase from 57,248 coenobia/cm³ in BRL-2 to as high as 1,256,924 coenobia/cm³ in BRL-3, while total algae increases from 270,322 coenobia/cm³ to as high as 2,760,743 coenobia/cm³. *Tetraedron*, most commonly found as a tychoplanktonic genus inhabiting shallow waters of lakes in nearshore locations intermingled with macrophytic vegetation (Prescott, 1962), also becomes more abundant. The dramatic increase in algae suggests a hypertrophic concentration of nutrients (Cronberg, 1982).

Algae Zone BRL-4

Scenedesmus declines abruptly from 20.9% at the top of BRL-3 to 3.5% at the bottom of BRL-4, then increases to 62.5% at 185 cm. From 185 cm *Scenedesmus* generally declines up to 130 cm where no *Scenedesmus* were recorded, then reappears at 125 cm and continues to increase in abundance (Plate 3).

Zone BRL-4 is bracketed by a bottom date of 8300 ± 190 B.P. and a top date of 6840 ± 200 B.P. This corresponds to the maximum of the warm and dry conditions of the mid-Holocene dry period, which occurred between 8000 and 4000 years ago (Webb and Bryson, 1972; Wright, 1971). At this time, the Prairie Peninsula reached its maximum eastward extent (Bernabo and Webb, 1977). During this period *Pediastrum Boryanum*, *Pediastrum integrum*, *Botryococcus*, and *Tetraedron* are also major algae contributors to the depositional sequence.

Algae Zone BRL-5

A third *Scenedesmus* peak (35.5%) occurs in Zone BRL-5, while *Botryococcus* increases slightly and then declines. *Pediastrum Boryanum* decreases to 0.0% in the middle of this subzone and then reappears in minor amounts, with *Pediastrum integrum* following a similar pattern. At the same time, *Tetraedron* becomes an occasionally occurring minor component (Plate 3).

Algae Zone BRL-6

Zone BRL-6 is characterized by a decrease in *Scenedesmus* and an increase in *Pediastrum Boryanum*, while *Botryococcus* remains relatively stable in low quantities (Plate 3).

Algae Zone BRL-7

Scenedesmus, *Botryococcus*, and *Pediastrum Boryanum* all continue to decline in Zone BRL-7. In Zone BRL-7, a small peak in filamentous algae occurs (Plate 3).

Discussion

The pollen spectra from Zone BRL-1 represents the Compositae-Cyperaceae Assemblage Zone of Cushing (1967). This zone is interpreted to represent an open environment, most likely tundra with occasional stands of spruce or outliers of individual spruce trees. Dwarf birch and willow were probably also present. At several sites in northeast Minnesota, the Compositae-Cyperaceae Assemblage Zone is associated with macrofossils of present day Arctic tundra species (Wright and Watts, 1969). The relatively high values of the upland taxa, *Artemisia*, also indicate open ground. It is also possible that the *Picea* pollen is the result of long distance air transport from areas to the south rather than from the local occurrence of spruce. At Kotiranta Lake, Weber Lake, Glatsch Lake, Blackhoof Lake, (Wright and Watts, 1969), Spider Creek (Baker, 1965), and Kylen Lake (Birks, 1981), *Picea* and *Larix*

macrofossils are absent in the Compositae-Cyperaceae Assemblage Zone indicating the lack of local spruce.

Although *Artemisia* is a common component of late glacial pollen assemblages, the genus includes both Arctic and prairie species (Wright, Winter, and Patten, 1963). Cyperaceae and Gramineae also contain taxa that are common in tundra regions; however, they are not diagnostic and members of these families are found in many different environments (Wright, Winter, and Patten, 1963). Insect fauna found in conjunction with the Compositae-Cyperaceae Assemblage Zone at the Norwood Site, Sibley County, Minnesota, indicate an open boreal climate associated with a tundra-like flora (Ashworth, Schwert, Watts, and Wright, 1981).

Zone BRL-2 represents the *Betula-Picea* Assemblage Zone of Cushing (1967). This zone is interpreted as shrub parkland in the vicinity of Big Rice Lake. At Kylen Lake, this zone has been interpreted by Birks (1981) as indicating forest-tundra of dwarf birch with scattered black and white spruce and tamarack. Dwarf willow was probably also present. The abundance of *Artemisia* and *Ambrosia*-type may indicate the presence of open barren ground. At Kylen Lake, this zone has been interpreted by Birks (1981) as indicating forest-tundra of dwarf birch with scattered black and white spruce and tamarack. At Weber Lake, the type locality for the *Betula-Picea* Assemblage Zone, this zone dates from 10,500 to 10,200 yr B.P. At Big Rice Lake the top of this zone dates at about 9,500 yr B.P.

In Zone BRL-3, *Picea* and *Pinus* combined are the most abundant pollen types. *Picea* values decrease as *Pinus* values increase. The deciduous taxa, *Quercus*,

Ulmus, *Fraxinus*, and *Betula* are also important. The zone represents the *Picea-Pinus* Assemblage Zone of Cushing (1967). The pollen spectra from Zone BRL-3 fits all of the criteria of the *Picea-Pinus* Assemblage Zone as defined by Cushing (1967) except that *Larix* does not continuously occur in values of more than 1%. This zone is divided into two subzones based on the *Abies* maximum in the upper subzone (BRL-3b). The *Ulmus* maximum that occurs as *Pinus* is replacing *Picea*, in Zone BRL-3, has been reported from many mid-western sites (Maher, 1977; Wright, 1968b). This zone is interpreted as representing a conifer-hardwood forest and dates from approximately 9,500-8,300 yr B.P. At Weber Lake the *Picea-Pinus* Assemblage Zone dates from approximately 10,200-9,000 yr B.P.

Pinus, *Betula*, and *Alnus* dominate Zone BRL-4 which represents the *Pinus-Betula-Alnus* Assemblage Zone as defined by Cushing (1967). A mixed conifer-hardwood forest is indicated by the Zone BRL-4 pollen spectra. This zone dates between 9,000 and 7,000 yr B.P. at Weber Lake (Fries, 1962). At Big Rice lake this zone dates from 8,300 to 6,840 yr B.P. Associated with this zone at Big Rice Lake is an increased sediment accumulation rate (0.72 mm/yr). Below Zone BRL-4 the sediment accumulation rate is 0.29 mm/yr and above Zone BRL-4 the sediment accumulation rate is 0.15 mm/yr. An increased sediment accumulation rate is also associated with this zone at Kylen Lake (Birks, 1981). The increased sediment accumulation rate may indicate an increase in sediment load to the lakes during the maximum of the Hypsithermal when warmer, drier conditions existed possibly creating less stable ground cover and an increase in erosion.

Gramineae, *Artemisia*, *Ambrosia*-type, and Chenopodiaceae/Amaranthaceae are all prominent in Zone BRL-4. The elevated levels of these pollen types may reflect the expansion of the prairie peninsula into western Minnesota reaching its maximum extent about 7,000 years ago as it expanded approximately 120 km northeast of the current prairie border (Wright, 1968a). At Kirchner Marsh, Watts and Winter (1966), record the increase in weedy annuals, including *Chenopodium*, between 7,000 and 5,000 B.P. They interpret the increase in weedy annuals as indicating a drop in lake level allowing these plants to colonize the newly exposed lake mud. Low water levels between 8,000 and 7,000 years ago are also indicated by an increase in *Chenopodium rubrum* at Martin Pond (McAndrews, 1966). The rise in Gramineae, *Artemisia*, *Ambrosia*-type, and Chenopodiaceae/Amaranthaceae in Zone BRL-4 probably indicate the lowering of lake level at this time allowing the expansion of weedy annuals in newly opened mudflats. The increase in Gramineae may indicate the introduction and expansion of wild rice in Big Rice Lake. A drop in lake level would increase the area conducive for the growth of wild rice which grows best in about 1.5 m or less of water (Vennum, 1988).

The *Quercus* maximum in Zone BRL-5 suggests the presence of oak in the vicinity of Big Rice Lake. The increase in oak is probably the result of warmer and drier conditions during the mid-Holocene warm, dry period. There is also a shift from *Pinus banksiana*/*P. resinosa* to *Pinus strobus* in this zone at approximately 6,800 yr B.P. The rise in white pine has been dated at approximately 7,200 yr B.P. at Jacobson Lake (Wright and Watts, 1969) and around 7,000 yr B.P. at Lake of the

Clouds (Craig, 1972). At Myrtle Lake, farther to the west, the white pine rise occurred sometime before 6,000 yr B.P. (Janssen, 1968). Although *Artemisia*, *Ambrosia*-type, and Chenopodiaceae/Amaranthaceae values all decrease in the upper portion of this zone, indicating a change in cooler and moister climatic conditions as the prairie peninsula receded to its current position and the lake level began to rise again. *Quercus* pollen values also decline in the upper part of Zone BRL-5 probably also the result of cooler moister climatic conditions. The pollen spectra from Zone BRL-5 indicate a continuation of the mixed conifer-hardwood forest previously established in the area with a shift from red/jack pine white pine dominance. Cushing (1967) did not establish regional pollen assemblage zones for pollen sequences occurring above the *Pinus-Betula-Alnus* assemblage zone because of the lack of data younger than 8,000 years old, therefore Zone BRL-5 cannot be assigned to a regional pollen assemblage zone.

The increase in Gramineae in Zone BRL-6 is attributed to an expansion of wild rice (*Zizania aquatica*) in the lake. Similar increases in Gramineae has been reported from Rice Lake, Becker County, Minnesota (McAndrews, 1969) and Marquette Pond, Beltrami County, Minnesota (Yourd, 1988) and attributed to the expansion of wild rice by the authors. Based the estimated date, wild rice probably established over most of the lake by 3,600 years ago. A date on charcoal from a Laurel feature from the Big Rice archaeological site, on the northern shore of Big Rice Lake, containing wild rice is $1,670 \pm 45$ yr B.P. (Rapp, Allert, and Peters, 1990). Four other dates on wild rice grains from the Big Rice site are:

1,910 \pm 100 yr B.P., 2,040 \pm 100 yr B.P., 2,072 \pm 90 yr B.P., and 600 \pm 60 yr B.P. (Valppu and Rapp, 2000). The dates from the wild rice grains indicate that wild rice was probably very abundant on Big Rice Lake no later than 2,000 years ago. The slight increase in *Picea* in this zone reflects the readvance of spruce back into the area as climatic conditions became cooler and moister.

Based on the small increase in *Ambrosia*-type percentage values and the increase in *Ambrosia*-type concentration, Zone BRL-7 is interpreted to reflect deforestation by Euro-American settlers about 1890 (Maher 1977). This zone is commonly found in the upper sediment of pollen cores in the midwest and is associated with deforestation and land clearance by pioneer settlement (Wright, 1971).

It is interesting to note the organic carbon values are more stable, but slightly lower in the section of the core that contains the high Gramineae values. The slightly lower organic carbon values may reflect an increase in biogenic silica in the form of phytoliths from wild rice. Gramineae is one of the plant families that produces abundant phytoliths (Rapp and Hill, 1998).

In Algae Zone BRL-1, the low algae concentrations indicate low lake productivity according to Birks (1976). Low productivity is also indicated by the lack of organic material in the sediments associated with this zone. *Pediastrum integrum* and *Pediastrum simplex* were found by Birks (1976) in association with pioneer macrophytes at Wolf Creek in central Minnesota.

In early stages Big Rice Lake was oligotrophic and the algae assemblage was represented by pioneer species such as *Pediastrum integrum* and *P. simplex*. As

sediment began to infill the lake, the water column became more eutrophic, as indicated by the increase in *P. Boryanum*. Shifts in the abundance of *Scenedesmus*, an indicator of high nutrient concentration (Cronberg 1982), indicate that Big Rice Lake has undergone three periods of hypertrophism. The first occurred after 9,510 yr B.P. when the watershed was covered by an open conifer-hardwood forest conducive to a high nutrient influx to the lake through runoff. The second period of hypertrophism correlates well with the maximum of the mid-Holocene warm and dry period when sediment accumulation increased and the water level probably dropped, concentrating available nutrients. The third period of hypertrophism can be correlated with an increase in deciduous trees such as oak and elm that may have increased available nutrients in the lake as a result of leaf litter influx.

The decrease in algae (mostly *Scenedesmus* and *Pediastrum*) in the upper 75 cm of the sediment core indicates a decline in eutrophication; however, this may be a result of the increase in wild rice in the lake. As a dominant macrophyte in the lake, wild rice may be utilizing a large portion of the available nutrients such as nitrogen out of the water column. If this is happening, it would make the water column more oligotrophic in nature and cause a decline in the abundance of algae. Currently not enough data are available to verify the effect wild rice may have on nutrient availability to the algae community in a wild rice lake. Wild rice may have also contributed to the decline in algae in the upper portion of the core by causing a reduction in the photic zone. Wild rice leaves float on the water surface during the

floating stage of its development (Vennum, 1988) therefore reducing the amount of sunlight entering the water column.

I have not been able to find any other reports in the literature to support this hypothesis. However, a similar phenomenon occurs in the Wolf Creek core (Birks, 1976). Birks (1976) recorded coenobia of *Botryococcus* and several species of *Pediastrum* during pollen counting. His data show a major decline in percentages and influx (coenobia/cm²/yr) of algae while Gramineae percentages and influx (grains/cm²/yr) increases. Birks (1976) notes the decline of *Pediastrum* in this zone but does not offer an interpretation. The decline in algae occurs in the portion of the core where the increase in Gramineae is attributed to the expansion of wild rice. However, at this time, a direct relationship between the decline in algae and the increase in Gramineae (presumably wild rice) cannot be demonstrated.

CLOQUET LAKE: LONG CORE

Cloquet Lake, the headwaters of the Cloquet River, is in sections 8 and 9, T57N, R9W of the Cloquet Lake 7.5' quadrangle, Lake County, Minnesota. Cloquet Lake was cored on 6 July 1988. A 438-cm core was extracted from near the center of the lake (UTM: 613947,5254565, Zone 15). Water depth at the coring site was 1.58 m.

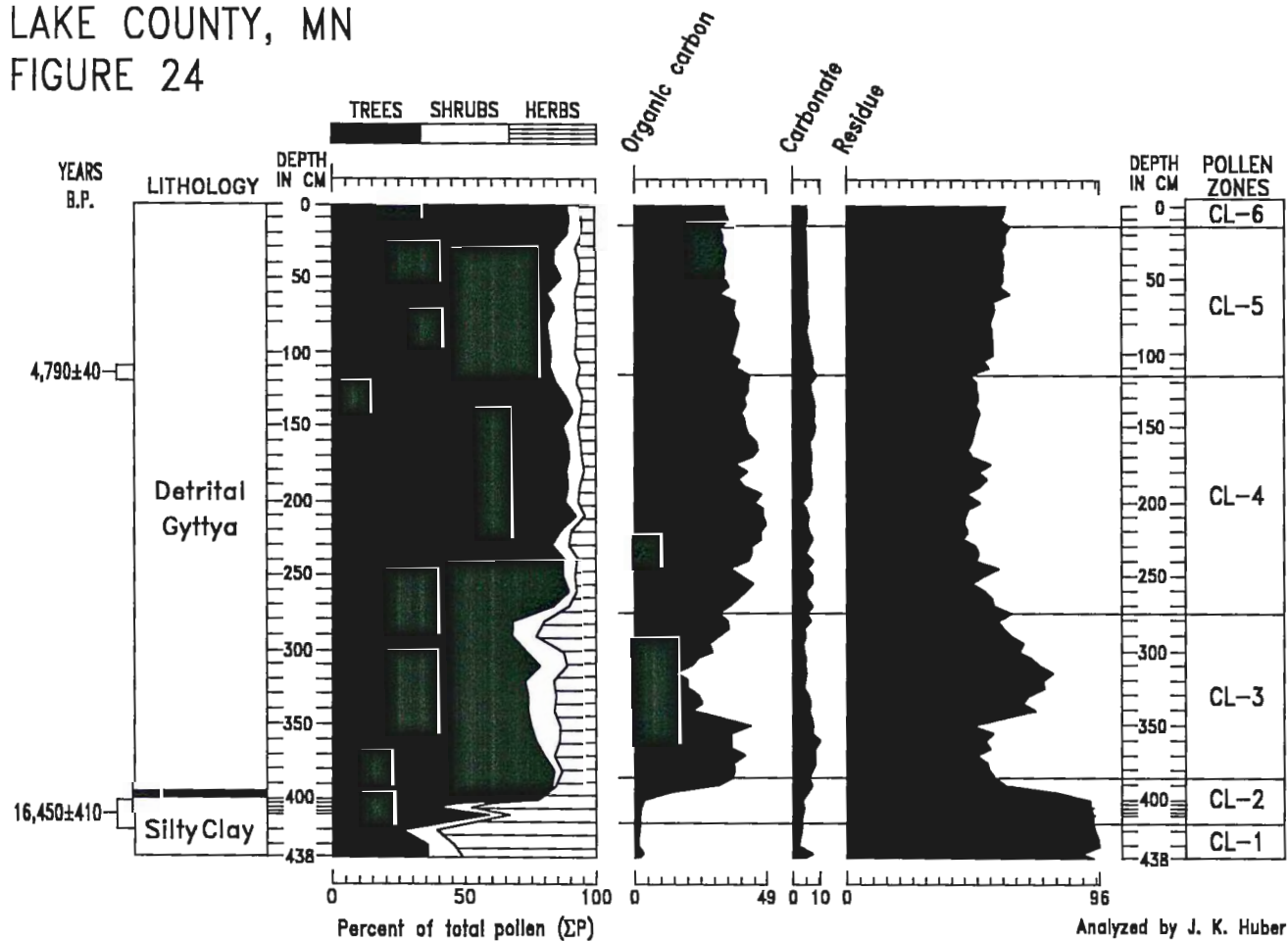
Stratigraphy

The core is composed of two distinct lithologic units separated by a 3-cm thick gravel layer. The upper 397 cm consists of detrital gyttja; below the gravel layer (400-438 cm) is silty gray clay.

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon and carbonate content along with ^{14}C dates are plotted in Figure 24. Significant and abrupt changes in organic carbon content occur in the Cloquet Lake core. Below 395 cm, organic carbon content is less than 4%. Organic carbon content ranges from 16% and 44% between 395 cm and 285 cm where a major maximum and minimum occur. Between 280 cm and 60 cm organic carbon content fluctuates between 31% and 49%. Above 110 cm, organic carbon content is relatively stable with values of 34-35% (Fig. 24). Carbonate content ranges from 2% to 10%, showing a similar silhouette to the organic carbon, but at much lower values (Fig. 24).

LOSS-ON-IGNITION PERCENTAGE DIAGRAM
CLOQUET LAKE
LAKE COUNTY, MN
FIGURE 24



Radiocarbon Dates

Three radiocarbon dates are available for the Cloquet Lake core. They are 110-120 cm, $4,790 \pm 40$ yr B.P. (PITT-1189); 387-397 cm, $5,105 \pm 60$ yr B.P. (PITT-1190); and 401-421 cm, $16,450 \pm 410$ yr B.P.

The lower most date ($16,450 \pm 410$ yr B.P.) should be viewed with circumspection based on technical problems using standard radiocarbon dating methods on the small sample used according to R. Stuckenrath, University of Pittsburgh, Radiocarbon Laboratory. The $16,450 \pm 410$ yr B.P. date is associated with the Compositae-Cyperaceae Assemblage Zone (Zone CL-1, Plate 4) that has a queried basal date of 16,150 yr B.P. and a midzone date of 13,500 yr B.P. at Kotiranta Lake (Wright and Watts, 1969). The equivalent zone at Big Rice Lake has a composite date of 12,040 yr B.P. At the type locality for this zone from Weber Lake (Fries, 1962), approximately 15 km to the west of Cloquet Lake, the zone is older than 10,500 yr. B.P. (Fries, 1962) but no basal date is available. At Kylen Lake, approximately 25 km to the southwest, Birks (1981) reports a basal date of $15,850 \pm 240$ yr B.P. and finds no reasons to doubt its validity.

Based on the regional glacial chronology of northeast Minnesota (Clayton and Moran, 1982; Mooers and Lehr, 1997), the Cloquet Lake area was ice covered at 16,000 yr B.P. and probably remained ice covered until approximately 13,500 yr B.P. or even later (Clayton and Moran, 1982). Only radiocarbon dates on wood were used by Clayton and Moran (1982) to develop their regional glacial chronology because dates from fine-grained organic sediment are commonly contaminated by

older carbon. In light of the work by Clayton and Moran (1982) and Mooers and Lehr (1997), the $16,450 \pm 410$ yr B.P. date for Cloquet Lake is most likely too old.

The $5,105 \pm 60$ yr B.P. date at 387-397 cm appears to be about 5,000 years too young. This date is associated with the pollen spectra where *Pinus* dominance begins (Plate 4) just above the top of the gravel layer that appears to be associated with a hiatus in the core. The beginning of *Pinus* dominance is dated at $9,150 \pm 130$ yr B.P. and the point at which *Pinus* begins to increase is dated at $10,180 \pm 160$ yr B.P. at Weber Lake (Fries, 1962). At Kylen Lake the initial increase in *Pinus* begins about 10,700 yr B.P. (Birks, 1981). The date is also below the rise in *Pinus strobus* beginning about 7,000 years ago (Wright, 1968b). The reason for the apparently young date for this section of the core is not easily explained. Possible explanations for the aberrant date is contamination during sampling or by mold growth during storage. Although not likely, it is also possible that rootlets of aquatic plants may have penetrated this section of the core. This date is not shown on the pollen diagram.

The youngest date, $4,790 \pm 40$ yr B.P., at 110-120 cm is somewhat older than expected. This date is associated with the increase in *Picea* that occurred approximately 4,000 years ago with climatic amelioration after the Hypsithermal. The increase in *Picea* occurred about 4,000 yr B.P. at Weber Lake (Wright, 1968b)

Pollen Zone CL-1

Zone CL-1 is characterized by nonarboreal pollen (NAP) of greater than 50%. The prominent NAP types found at Cloquet Lake are Cyperaceae (17-24%), *Ambrosia*-type, (6-19%), *Artemisia* (4-9%), Gramineae (3-8%), and Tubuliflorae (1-3%). *Picea* (12-24%), *Salix* (8-10%), Cupressaceae (4-6%), *Quercus* (3-5%), and *Alnus* (1-3%) are the most abundant AP types. The vascular cryptogams Dryopteris-type and Athyrium Filix-femina both have small maxima in this zone (Plate 4).

Pollen Zone CL-2

Picea reaches its maximum abundance in Zone CL-2 (48%). *Pinus banksiana*/*P. resinosa* (jack/red pine) which occurs in only trace amounts in Zone CL-1, becomes the dominant taxon at the top of Zone CL-2. Cyperaceae is still prominent but declining. *Artemisia* and *Ambrosia*-type values also decrease. Cupressaceae, *Salix*, Cyperaceae, Tubuliflorae, Gramineae, and *Urtica*-type all have maxima at 407 cm (Plate 4).

Pollen Zone CL-3

Pinus banksiana/*P. resinosa* (32-46%), *Betula* (9-17%), and *Alnus* (1-10%) are the dominant AP types found in Zone CL-3. *Picea* is also prominent but declines to less than 5% at the top of Zone CL-3. *Abies* is present with values of 2% or less. Cupressaceae, *Quercus*, *Ulmus*, *Ostrya*/*Carpinus*, *Fraxinus*, and *Salix* are also important. Cyperaceae, *Artemisia*, *Ambrosia*-type, Gramineae, and

Chenopodiaceae/Amaranthaceae maintain values of 1% to 6%. *Equisetum* and *Pteridium* are higher in this zone than any other zone. An *Isoetes* maximum occurs at the top of Zone CL-3 and the bottom of Zone CL-4. NAP is 20% or less than throughout this zone (Plate 4).

Pollen Zone CL-4

Zone CL-4 is characterized by the transition of *Pinus banksiana*/*P. resinosa* to *Pinus strobus* (white pine). *Betula* and *Alnus* both decline as *Pinus* increases, while *Picea* remains consistently present in low amounts. NAP is also low, less than 10%. Cyperaceae, *Artemisia*, *Ambrosia*-type, Chenopodiaceae/Amaranthaceae, and Gramineae, are the most abundant herbs with values of less than 5%. After an initial decline, *Isoetes* is present at approximately 1% (Plate 4).

Pollen Zone CL-5

In Zone CL-5, an overall increase in *Betula*, *Alnus*, *Picea*, and Cupressaceae occurs as *Pinus* declines. *Quercus* and *Ostrya/Carpinus* also increase. NAP continues to remain low. *Artemisia* and Gramineae values increase slightly (Plate 4).

Pollen Zone CL-6

The rise of *Ambrosia*-type pollen in the upper sediment of pollen cores in the midwest, associated with deforestation and land clearance by pioneer settlement (Wright, 1971) is not readily apparent at the top of Zone CL-6. However, there is an

increase in *Ambrosia*-type pollen concentration from 3,340 grains/cm³ of wet sediment in sample level 19-20 cm to 16,6690 grains/cm³ of wet sediment in sample level 9-10 cm and then a decrease to 6,675 grains/cm³ of wet sediment in the uppermost level (0-1 cm). *Pinus* attains a maximum of 52% in the uppermost level (Plate 4).

Algae Zone CLA-1

Zone CLA-1 represents the initial period of algal colonization in the lake. Algae concentrations are very low, 700-1,100 coenobia/cm³ of wet sediment, and only eight different taxa are present. Dinoflagellate cysts (dormant, thick-walled cells) were also observed in their greatest abundance in Zone CLA-1 (Plate 5); however their paleoecological significance has not yet been determined (Norris and McAndrews, 1970).

Algae Zone CLA-2

After an initial period of colonization, *Scenedesmus*, a colonial green algae (Chlorophycophyta) indicative of elevated nutrient levels (Cronberg, 1982) is the predominant taxon. The *Scenedesmus* maximum in Zone CLA-2 varies from 38% to 65%. *Tetraedron* is a tychoplanktonic genus most commonly found in shallow, nearshore waters in association with macrophytic vegetation (Prescott, 1982) has a maximum of 18% at 402.5 cm, then falls to approximately 2% throughout the rest of the zone. *Zygnema*-type (1-7%), *Spirogyra*-type (about 1%), and *Mougeotia* (<1%) are indicators of stagnant, shallow, and more or less mesotrophic habitats (Van Geel,

1978). *Pediastrum Boryanum* is an indicator of lake eutrophication (Cronberg, 1982), has values of 1% to 10%. *Botryococcus* and *Coelastrum* are both prominent. Blue green algae (Cyanochloronta) of *Gloeotrichia*-type, a nitrogen fixing algae (Van Geel, Coope, and Van Der Hammen, 1989), makes its initial appearance and reaches 4% (Plate 5).

Algae Zone CLA-3

In Zone CLA-3, *Scenedesmus* attains a second maximum of 61%. There is a *Zygnema*-type maximum in the lower portion of the zone (9%) and then *Zygnema*-type declines to less than 1%. *Gloeotrichia*-type values range from 3% to 6%.

Tetraedron and *Botryococcus* maintain values of 3% or less. *Coelastrum* increases slightly in the upper part of the zone. *Pediastrum Boryanum* has a maximum of 11% and then declines to 3%. *Pediastrum duplex* var. *clathratum* has a small maximum at 300 cm (Plate 5).

Algae Zone CLA-4

A third *Scenedesmus* maximum occurs in Zone CLA-4 and there is a *Gloeotrichia*-type maximum at 200 cm. *Tetraedron*, *Botryococcus*, *Coelastrum*, and *Zygnema*-type values fall to less than 3%. *Pediastrum Boryanum* values fluctuate between 4% and 6%. There is a small *Pediastrum duplex* var. *clathratum* maximum in the middle of Zone CLA-4 (Plate 5).

Algae Zone CLA-5

In Zone CLA-6, a fourth *Scenedesmus* maximum occurs. This *Scenedesmus* maximum is smaller than the previous three. A maximum of *Tetraedron* (9%) also occurs. *Gloeotrichia*-type is still prominent. There is a *Botryococcus* maximum at the bottom of this zone and *Zygnema*-type values increase at the top. *Pediastrum Boryanum* values remain consistent at approximately 8% (Plate 5).

Algae Zone CLA-6

The fifth and smallest *Scenedesmus* maximum occurs in Zone CLA-6. Two *Gloeotrichia*-type maxima also occur. After a small maximum (6%) at the base of the zone, *Botryococcus* declines to about 1%. *Tetraedron* also has a maximum at the bottom of the zone and then decreases. *Spirogyra*-type increases slightly and *Pediastrum Boryanum* values remain fairly constant (Plate 5).

Algae Zone CLA-7

In Zone CLA-7, *Scenedesmus* and *Gloeotrichia*-type decline to trace amounts. *Pediastrum Boryanum* values also decrease. *Spirogyra*-type values increase then decrease in this zone. *Zygnema*-type values increase in the upper part of Zone CLA-7. *Tetraedron* and *Botryococcus* are present as minor components (Plate 5).

Discussion

Zone CL-1, at Cloquet Lake, is the Compositae-Cyperaceae Assemblage Zone of Cushing (1967) and represents an open environment, most likely tundra with *Salix* and Cupressaceae and occasional stands of spruce or outliers of individual spruce trees. Unlike at Big Rice Lake and Weber Lake, *Betula* is virtually absent at this time at Cloquet Lake. Zone CL-1 is more similar to Compositae-Cyperaceae zone at Kylen Lake, rather than the equivalent zone at the closer Weber Lake.

The pollen spectra in Zone CL-2 is indicative of a conifer-hardwood forest and most closely correlates to the *Picea-Pinus* Assemblage Zone of Cushing (1967). However, Zone CL-2 appears to have a hiatus and could be divided into two separate zones. In northeast Minnesota the *Betula-Picea* Assemblage Zone occurs between the Compositae-Cyperaceae Assemblage Zone and the *Picea-Pinus* Assemblage Zone (Cushing, 1967).

Although missing at Cloquet Lake, the *Betula-Picea* Regional Assemblage Zone, *Betula* is the dominant pollen type in the *Betula-Picea* Regional Assemblage Zone; the next most frequent is *Picea*; also of relative importance is *Salix* (more than 3%). Pollen of other trees and shrubs is found at less than 5%. Nonarboreal (NAP) pollen ranges from 20-40%. Cyperaceae and *Artemisia* are the major NAP taxa (Cushing, 1967). The type locality is Zone 2 of core C:1 from Weber Lake (Fries, 1962) approximately 15 km to the west of Cloquet Lake. At Weber Lake this zone dates from about 10,500 to 10,200 yr B.P. No part of Zone CL-2 fit the criteria of

the *Betula-Picea* Regional Assemblage Zone, either *Betula* is absent or *Pinus* values are too high.

The lack of evidence for the *Betula-Picea* Assemblage Zone could reflect an absence of *Betula* in the watershed or a hiatus in the depositional record. It seems unlikely that the lack of evidence for the *Betula-Picea* Assemblage Zone reflects the absence of *Betula* in the Cloquet Lake watershed when this zone occurs at Weber Lake (Fries, 1962) approximately 15 km to the west. *Betula* produces large quantities of pollen, is wind pollinated, and can be transported long distances via air currents (Faegri and Iverson, 1975; Moore and Webb, 1978); therefore, even if *Betula* did not occur in the immediate vicinity of Cloquet Lake, it should be present as part of the regional pollen assemblage. Thus the only alternative reason for the absence of the *Betula-Picea* pollen assemblage zone at Cloquet Lake is a hiatus in the depositional record.

The 3-cm thick gravel layer at 397-400 cm in the core appears to mark the lower boundary of the hiatus and indicates a change in the sedimentation environment in the Cloquet Lake basin. A hiatus is also indicated by a sudden rise or decline in taxon at the gravel layer. Correlation of the Cloquet Lake pollen sequence with the Weber Lake pollen assemblage zones indicates that for a period of approximately 500 years conditions were unfavorable for sediment accumulation in the lake or if sediment accumulation occurred, approximately 500 years of sediment was removed by erosion. Around 10,000 B.P., sediment accumulation resumed as conditions became more favorable. Changing conditions in lake sediment deposition can be

explained in a variety of ways depending on the lake basin type and the processes that formed the basin. One possible explanation for the hiatus in the Cloquet Lake sediments is that the lake basin dried up or was drained. This hypothesis is substantiated by the presence of the gravel layer, which could have been deposited by sheet wash while the lake basin was dry. The increase in abundance of degraded pollen in this section of the core (Plate 4) indicates the occurrence of oxidation processes that destroy pollen (King, 1985). These data also suggest that the lake basin became dry. Erosion of the lake sediment could have occurred during the period of time the lake was dry.

Cloquet Lake is located within the Highland Moraine (Wright, 1972) and occurs in a delta apron of ice core moraine deposits (C.L. Matsch, personal communication, 1992). Therefore, it is possible that the lower silty clay sediment was deposited in an ice core depression basin. As the ice core melted, the initial lake basin drained, exposing the clays, and allowing the pollen to become oxidized and the gravel layer to be deposited. With subsequent melting of the ice block underlying the basin, the silty clay gradually subsided into a second basin that was formed, creating the current Cloquet Lake basin. After the stabilization of the second Cloquet Lake basin occurred, gyttja began to accumulate in the lake.

Zone CL-3 fits very well with the criteria for the *Pinus-Betula-Alnus* Assemblage Zone as defined by Cushing (1967). *Pinus* is the most abundant taxon, *Betula* is more than 10%, *Alnus* is greater than 5%, and *Abies* occurs in values of more than 1%. *Ulmus* and *Quercus* values are less than 5% each, and NAP is less

than 15%, but increases at the top of the zone. The small maxima in *Artemisia*, *Ambrosia*-type, Gramineae, and Chenopodiaceae/Amaranthaceae at the top of this zone probably reflect warmer and drier conditions at the maximum of the Hypsithermal approximately 7,000 years ago when the prairie peninsula expanded to the east (Wright, 1968a). The increase prairie-type taxa is probably the result of increased forest openings or the lowering of the lake level allowing the growth of weedy annuals similar to the situation recorded at Kirchner Marsh for this time period (Watts and Winter, 1966). The pollen spectra in Zone CL-3 indicate that a mixed conifer-hardwood forest had developed in the Cloquet Lake vicinity.

Zone CL-4 is dominated by very high values of *Pinus*. *Pinus strobus* increases as *Pinus banksiana*/*P. resinosa* decreases. *Betula* and *Alnus* values are reduced and *Picea* percentages are low. In this zone herbaceous pollen values are also low. The deciduous taxa, *Quercus*, *Ulmus*, *Ostrya/Carpinus*, and *Fraxinus* are the most abundant minor components. During Zone CL-4, a succession from red and/or jack pine to white pine occurs in a mixed conifer-hardwood forest in the Cloquet Lake watershed. Based on correlation of the abrupt increase in *Pinus strobus* to dated sites, this zone dates to approximately 7,000 yr B.P. at bottom and ends at about 4,800 yr B.P.

There is a decrease in *Pinus* and an increase in *Picea* and Cupressaceae in Zone CL-5. A significant increase in *Betula* and *Alnus* occurs, as well as an increase in abundance of hardwoods. The mixed conifer-hardwood forest continues in the Cloquet Lake watershed but was more interspersed with birch and other deciduous

taxa. The increase in deciduous taxa may reflect the establishment of the predominantly hardwood forest in the North Shore Highlands along the north shore of Lake Superior. The eastern side of Cloquet Lake borders the Highland Moraine.

The increase in *Ambrosia*-type pollen concentration in Zone CL-6 indicates deforestation and land clearance by pioneer settlement in the vicinity of the Cloquet Lake watershed. In this part of Minnesota, a beginning date for the *Ambrosia*-type pollen rise is approximately 1890 (Maher, 1977). The *Pinus* maximum in the uppermost sample may reflect the over representation of pine in areas that have been clear cut or the reestablishment of pine as second growth timber.

The nonsiliceous algae associated with the pollen sequence from Cloquet Lake, indicate that several apparent fluctuations in the trophic status of the lake have occurred throughout its history. Zone CLA-1 represents the initial period of algal colonization in the lake.

After an initial period of colonization, *Scenedesmus*, indicative of elevated nutrient levels (Cronberg, 1982) is the predominant taxon. *Scenedesmus* maxima in the sequence indicate that Cloquet Lake has undergone five cycles of nutrient enrichment. In the upper portion of the sequence (Zone CLA-7), *Scenedesmus* abundance decreases significantly.

Pediastrum Boryanum, an indicator of lake eutrophication (Cronberg, 1982), is present in trace amounts in CLA-1 and occurs as the second most important taxon throughout the rest of the sequence. *Zygnema*-type and/or *Spirogyra*-type resting

spores, which are present in all zones, indicate stagnant, shallow, and generally mesotrophic conditions (Van Geel, 1978).

Scenedesmus and/or *Pediastrum* maxima associated with the late glacial spruce zone (Crisman, 1978; Huber, 1988, 1989; Huber and Overstreet, 1990) have been documented at sites in Minnesota and Wisconsin. These maxima have been interpreted as indicating periods of increased productivity. The five cycles of nutrient enrichment indicated by the *Scenedesmus* maxima suggest that Cloquet Lake has been nutrient rich throughout most of its history. The oscillations in *Scenedesmus* abundance may have resulted from changing environmental and/or limnologic conditions in the Cloquet Lake watershed after the lake basin was formed. The nonsiliceous algae record suggests that Cloquet Lake has become more oligotrophic in relatively recent times.

GEGOKA LAKE: LONG CORE

Gegoka Lake is in Lake County, Minnesota, in sections 27 and 28, T60N, R9W of the Mitawan Lake 7.5 minute quadrangle. Gegoka Lake was cored on 2 October 1992. A 262-cm was extracted from 1.44 m of water in the deepest area of the northern Gegoka Lake basin at Core Site 1 (UTM: 614212,5271741, Zone 15). The Misiano site on McDougal Lake is approximately 4 km southwest of Gegoka Lake.

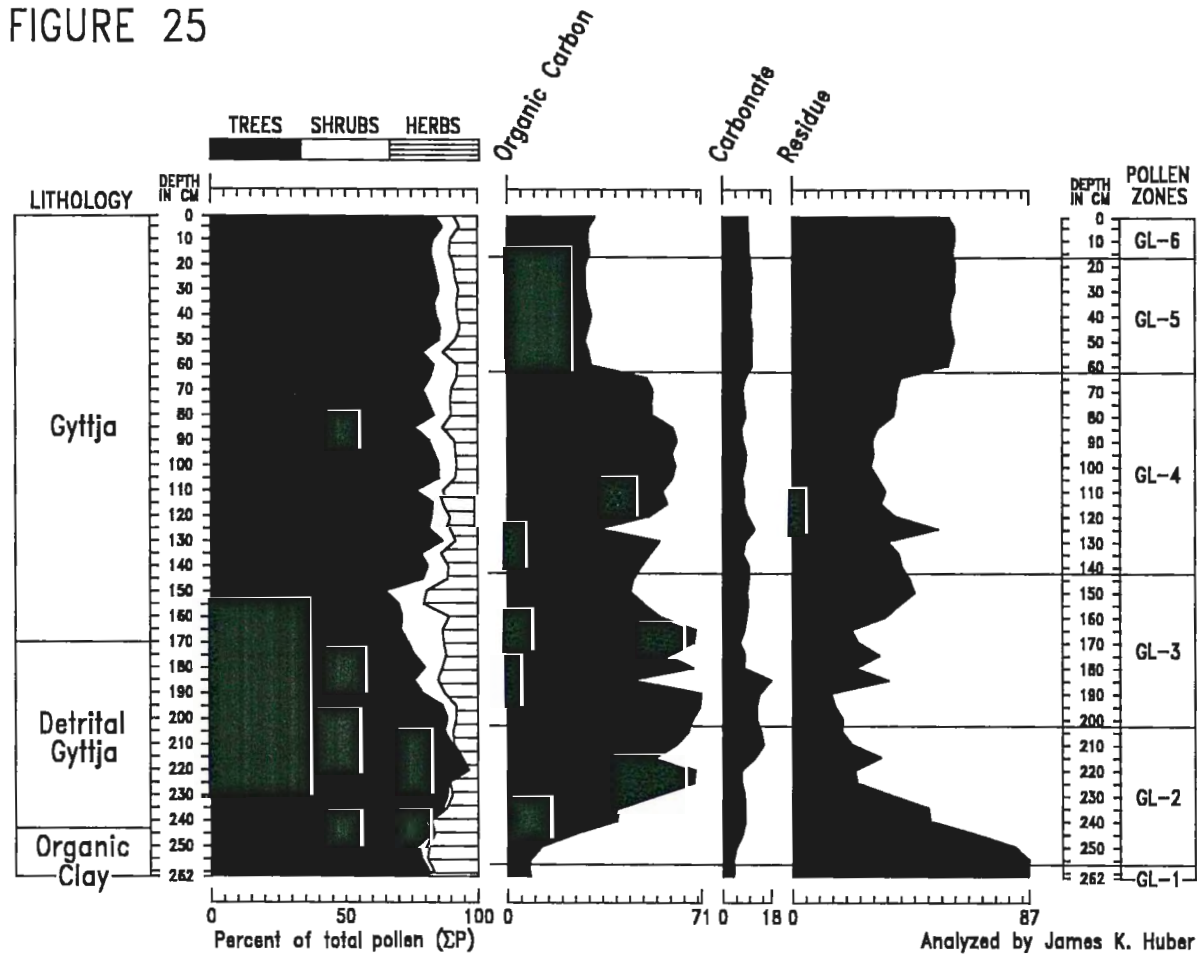
Stratigraphy

The core is composed of three major lithologies: 0-170 cm, olive gray gyttja; 170-243 cm, olive gray detrital gyttja; and 243-262 cm, dark olive gray organic clay.

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon ranges from 8% to 31% with the largest value occurring at both 190 cm and 195 cm (Fig. 25). From 262-245 cm, organic carbon increases from 8% to 25%. The highest percentages of organic carbon occur between 245-60 cm, fluctuating from 40% to 71%. Above 60 cm, organic carbon averages approximately 30% (Fig. 25). Carbonate content ranges from 7% to 18%. Below 215 cm carbonate occurs at values of less than 10%, increasing to 18% at 185 cm. From 185-65 cm carbonate carbon values are 7% to 12%. Carbonate values are fairly constant at approximately 10% above 60 cm (Fig. 25).

LOSS-ON-IGNITION PERCENTAGE DIAGRAM
 GEGOKA LAKE
 LAKE COUNTY, MINNESOTA
 FIGURE 25



Pollen Zone GL-1

Zone GL-1 is characterized by the highest NAP value in the core (21%). The prominent NAP types found at Gegoka Lake are Cyperaceae, *Artemisia*, *Ambrosia*-type, and Gramineae. Cyperaceae and *Artemisia* both attain maxima of 10.6% and 4% respectively. *Picea* (32% to 38%), *Pinus banksiana/resinosa* (20% to 21%), and *Betula* (16% to 8%) are the most abundant AP types. *Betula* attains a maxima in this zone. Cupressaceae, *Larix*, *Quercus*, *Ulmus*, *Ostrya/Carpinus*, and *Fraxinus nigra* all occur as minor components (Plate 6).

The only occurrence of the fungal hyphopodia *Gaeumannomyces* cf. *caricis* (0.2%) is also in this zone (Plate 6). Van Geel (1986) reports a correlation between the presence of this fungi and the local appearance of Cyperaceae in peat, which indicates that the Cyperaceae pollen is probably from a local source.

Zone GL-2

AP ranges from 81% to 97% in Zone GL-2. *Pinus banksiana/resinosa* reaches its maximum abundance at 215 cm in Zone GL-2 with values ranging from 25% to 71%; at the upper range it becomes the dominant taxon. *Picea* decreases from a maximum of 30% to 4%. *Betula* declines from 8% at the bottom of Zone GL-2 to approximately 4% in the middle of the zone, then increases to 17% at the top. *Quercus* and *Ulmus* both attain maxima between 250 cm and 230 cm. *Ostrya/Carpinus* also has a maxima between 235-230 cm. *Pinus strobus*,

Cupressaceae, and *Larix* remain consistent minor components with values of less than 3%. *Alnus* and *Salix* are fairly consistent minor shrubs in Zone GL-2 (Plate 6).

In Zone GL-2, the prominent NAP types continue to be Cyperaceae, *Artemisia*, *Ambrosia*-type, and Gramineae. The vascular cryptogam, *Pteridium*-type, is also a prominent minor component in this zone at less than 3%. Cyperaceae, *Artemisia*, *Ambrosia*-type, and Gramineae generally decline in this zone (Plate 6).

Pollen Zone GL-3

In zone GL-3, AP values vary from 80% to 92%. *Pinus banksiana*/*P. resinosa*, *Betula*, *Alnus*, and *Picea* are the dominant AP types found in Zone GL-3. *Pinus banksiana*/*P. resinosa* values (33% to 58%) decrease in this zone after a maxima at 195 cm. *Betula* ranges from 11% to 22%; *Picea* peaks at 7% at 175 cm then declines to less than 2% at the top of this zone. *Pinus strobus* increases from 2% to 7% in Zone GL-3. Cupressaceae, *Quercus*, *Ulmus*, *Ostrya*/*Carpinus*, and *Fraxinus nigra* all maintain low (less than 3%) but consistent values. *Salix* continues as a consistent minor shrubs in Zone GL-3 (Plate 6).

In Zone GL-3, Cyperaceae, Gramineae, *Artemisia*, *Ambrosia*-type, Tubuliflorae, Chenopodiaceae/Amaranthaceae, *Pteridium*-type, *Equisetum*, and *Dryopteris*-type are the most prominent herbs with values of up to 5% (Plate 6).

Pollen Zone GL-4

In Zone GL-4, AP values range from 86% to 92%. Zone GL-4 is characterized by the transition of *Pinus banksiana/resinosa* to *Pinus strobus*. *Pinus strobus* increases from 15% to 40% while *Pinus banksiana/resinosa* declines from 47% to 21%. *Betula* increases from 8% to a maximum of 19%, then decreases to 14% at the top of Zone GL-4. *Picea* values are low, 3% or less. *Quercus* is the most dominant deciduous component with values of 1% to 4% followed by *Ulmus*, *Ostrya/Carpinus*, and *Fraxinus nigra* with values of 2% or less. Cupressaceae and *Populus* maintain low (less than 2%) but consistent values. *Alnus* continues as one of the most prominent AP types in Zone GL-4 with values of 4% to 10%. *Salix* and *Corylus* continue as consistent minor shrubs in Zone GL-4 (Plate 6).

Cyperaceae, Gramineae, *Artemisia*, *Ambrosia*-type, *Pteridium*-type, and Chenopodiaceae/Amaranthaceae continue to be the most prominent herbs in Zone GL-4 with values of up to 4% (Plate 6).

Pollen Zone GL-5

AP values range from 87% to 93% in zone GL-5. This zone is characterized by an increase in *Picea* (3% to 8%) and *Betula* (11% to 19%) and a general decrease in *Pinus* (62% to 53%). Cupressaceae and *Larix* are both more abundant in Zone GL-5 with values of up to 3.4% and 1.7%, respectively. Although less abundant than in Zone GL-4, *Quercus* is still the most dominant deciduous component with values of up to 2%. *Abies*, *Ulmus*, *Ostrya/Carpinus*, *Fraxinus nigra*, *Fraxinus*

pennsylvanica/americana, and *Populus* maintain low but fairly consistent values.

Except for *Alnus* (5-8%), shrub values are very low in Zone GL-5 (Plate 6).

The most prominent herbs in Zone GL-5 are Cyperaceae, Gramineae, *Artemisia*, *Ambrosia*-type with values of 4% or less. Tubuliflorae, *Pteridium*-type, Chenopodiaceae/Amaranthaceae, and *Dryopteris*-type are consistently present in trace amounts (Plate 6).

Pollen Zone GL-6

In zone GL-6, AP values range from 89% to 93%. An increase in Gramineae characterizes this zone. Gramineae values increase from 2.2% at the top of Zone GL-5 to 5.2 at the beginning of Zone GL-6, falling to 3.6% at the top of the core. Other prominent herbs include Cyperaceae, *Artemisia*, and *Ambrosia*-type at less than 2%. Tubuliflorae, *Pteridium*-type, Chenopodiaceae/Amaranthaceae, and *Dryopteris*-type are consistently present in trace amounts (Plate 6).

Picea increases from 5% to 8% and *Betula* decreases from 19% to 15%. *Pinus strobus* ranges from 32% to 38% while *Pinus banksiana/resinosa* ranges from 16% to 20%. Cupressaceae, *Larix*, *Abies*, and *Quercus* are conspicuous minor components in Zone GL-6. *Ulmus*, *Ostrya/Carpinus*, *Fraxinus nigra*, and *Populus* occur with low consistent values. *Alnus* ranges from 5% to 7% in Zone GL-6 (Plate 6).

Algae Zone GLA-1

The most abundant algae in Zone GLA-1 is *Pediastrum Boryanum*, increasing from 10% at the base of the core to a maximum of 17% at 245 cm, *Pediastrum Boryanum* then declines to 7% at the top of the zone. *Pediastrum Boryanum* var. *longicorne* occurs consistently at approximately 1%. *Pediastrum integrum* var. *scutum* has a maxima of 4% in the lower part of this zone, declining to 0.1% at the top of the zone. *Coelastrum* also has greatest abundance in Zone GLA-1 (5%). *Tetraedron* values range from 0% to 2% and *Gloeotrichia*-type fluctuates between 0% and 3%. *Scenedesmus* occurs at 2% in the lower part of the zone and increases to 10% at the top (Plate 7).

Algae Zone GLA-2

Zone GLA-2 is characterized by a decrease in *Pediastrum Boryanum* from 5% at the bottom of the zone to 1% at the top. *Scenedesmus* increases from 9% at 230 cm to 54% at 210 cm, then decreases to 12% at the top (205 cm). *Gloeotrichia*-type attains its greatest value 9% at 220 cm. *Pediastrum Boryanum* var. *longicorne* continues to occur consistently at approximately 1%. *Tetraedron*, *Botryococcus*, and *Coelastrum* are also present with low values (Plate 7).

Algae Zone GLA-3

Within Zone GLA-3, three *Scenedesmus* maxima of 50% at 190 cm, 65% at 165 cm, and 47% at 150 cm occur. *Gloeotrichia*-type also has several minor maxima with values ranging from 1-1.5%. *Botryococcus* and *Pediastrum Boryanum* are both continuously present with values of less than 3% (Plate 7).

Algae Zone GLA-4

The prominent features of Zone GLA-4 are the two *Scenedesmus* maxima. *Scenedesmus* increases from 10% at 125 cm to 55% at 105 cm, decreases to 10%, increasing to 85 % at 85 and 80 cm, and then decreases to 32% at 60 cm (top of Zone GLA-4). *Gloeotrichia*-type is a prominent minor component occurring at less than 2%. *Botryococcus* has a small maxima (3%), *Tetraedron* has a maxima (2%) at 110 cm, and *Pediastrum Boryanum* maxima (2%) occurs at 60 cm. Dinoflagellate (Pyrrophycophyta) cysts (dormant thick walled cells) occur for the first time in this zone (Plate 7). The paleoecological significance of the dinoflagellate cysts are not well understood. Work by Norris and McAndrews (1970) indicates that changes in the abundance of dinoflagellate cysts is probably the result of local environmental change rather than climatic change.

Algae Zone GLA-5

Zone GLA-5 is characterized by a marked decrease in algae abundance and diversity. *Scenedesmus* values decline from 32% at the top of Zone GLA-4, to less than 10% throughout Zone GLA-5. *Gloeotrichia*-type becomes more prominent with values ranging from 2% to 7.5%. *Zygnema*-type, an indicator of mesotrophic habitats (Van Geel, 1978), is also more prominent than previously with values of up to 2% (Plate 7).

Discussion

At Gegoka Lake, the oldest sediment recovered did not encompass the Regional Compositae-Cyperaceae Pollen Assemblage Zone of Cushing (1967). Apparently sediments of this age were not recovered during core retrieval or the lake did not exist at this time. However, subsequent cores from Gegoka Lake may yield older sediments.

At Gegoka Lake, the Regional *Betula-Picea* Pollen Assemblage Zone (Cushing, 1967) is represented by Zone GL-1, even though it does not fit all the criteria for the Regional *Betula-Picea* Pollen Assemblage Zone.

The moderate values of *Picea* and *Pinus*, the *Betula* maxima, and the significant abundance of herbaceous pollen indicate that Zone GL-1 is a transitional zone. The vegetation is changing from that of a shrub parkland to an open conifer forest. At Weber Lake, the Regional *Betula-Picea* Pollen Assemblage Zone dates from 10,500 yr B.P. to 10,200 yr B.P. (Fries, 1962).

Zone GL-2 is the Regional *Picea-Pinus* Pollen Assemblage Zone of Cushing (1967). *Pinus* values increase as *Picea* declines; herbs are less than 20%. *Larix* is consistently present and deciduous taxa are important. A conifer-hardwood forest is represented by the Zone GL-2 pollen spectra. This zone dates from approximately 10,200-9,000 yr B.P. at Weber Lake (Fries, 1962). Van Geel (1986) reports a correlation between the presence of the fungi *Gaeumannomyces* cf. *caricis* and the local appearance of Cyperaceae in peat, which indicates that the Cyperaceae pollen is probably from a local source in GL-2.

Pinus banksiana/*P. resinosa*, *Betula*, and *Alnus* are the most important pollen types in Zone GL-3. At the top of the zone, herbs increase. The pollen spectra in Zone GL-3 indicate a mixed conifer-hardwood forest has become established in the Gegoka Lake watershed. The Regional *Pinus-Betula-Alnus* Pollen Assemblage Zone (Cushing, 1967) is represented by Zone GL-3. At Weber Lake this zone dates from about 9,000 to 7,000 yr. B.P. (Fries, 1962). The small maxima in Gramineae, Ambrosia-type, and Chenopodiaceae in the upper part of this zone may indicate the maximum of the Hypsithermal as the Prairie Peninsula expanded approximately 120 km to the east about 7,000 years ago (Wright, 1968a). The increase prairie-type taxa are probably the result of increased forest openings or the lowering of the lake level, which allowed the growth of weedy annuals in mudflats (Watts and Winter, 1966).

In Zone GL-4, *Pinus*, *Betula*, and *Alnus* continue to be the most prominent pollen types, but the composition of the forest is changing. Some of the deciduous components are increasing at the expense of *Picea*. In addition, a succession from

Pinus banksiana/*P. resinosa* to *Pinus strobus* occurs in a mixed conifer-hardwood forest. The rise in *Pinus strobus* has been dated at approximately 7,200 yr B.P. at Jacobson Lake (Wright and Watts, 1969), at about 6,850 yr B.P. at Big Rice Lake, and around 7,000 yr B.P. at Lake of the Clouds (Craig, 1972).

In Zone GL-5, the mixed conifer-hardwood forest continues to change as *Pinus* decreases while *Picea* and *Betula* increase. The increase in abundance of *Picea*, Cupressaceae, and *Larix* suggest that the wet ground habitat is expanding in the previously white pine dominated Gegoka Lake watershed. The establishment of wild rice (*Zizania aquatica*) in Gegoka Lake is suggested by the small increase in Gramineae values in Zone GL-5.

The dominate pollen taxa are *Pinus*, *Picea*, *Betula*, and *Alnus* in Zone GL-6, which indicate that the mixed conifer-hardwood forest present at the beginning of Zone GL-5 has continued to the present.

Although the values are low, Gramineae becomes more abundant in Zone GL-6. This increase in Gramineae pollen is attributed to the expansion of wild rice, which is currently growing over much of Gegoka Lake. The increase in Gramineae abundance is lower than that found at other rice lakes (McAndrews, 1969; Yourd, 1988) and may indicate that the expansion of wild rice in Gegoka Lake is a relatively recent event.

At the beginning of Zone GLA-1, algae are well established. The maximum of *Pediastrum Boryanum*, an indicator of lake eutrophication (Cronberg, 1982), and the increase in *Scenedesmus*, indicative of elevated nutrient levels (Cronberg, 1982),

both colonial green algae (Chlorophycophyta), indicate that Gegoka Lake was experiencing a period of increased nutrient influx.

In the Gegoka Lake algae sequence, the *Pediastrum Boryanum* maximum (Plate 7) correlates with the late glacial *Picea* zone. *Scenedesmus* and/or *Pediastrum* maxima associated with the late glacial spruce zone have been observed at sites in Minnesota and Wisconsin. These maxima have been interpreted as indicating periods of increased productivity. Crisman (1978) reviewed the data from six sites in Minnesota from which *Pediastrum* values were recorded as part of the palynological investigations. At all six sites, Crisman (1978) found that the late glacial *Picea* zone was characterized by a *Pediastrum* peak, which is interpreted as indicating increased productivity. Elevated *Pediastrum* values associated with the late glacial *Picea* zone have also been documented at Kylen Lake (Birks, 1981), Myrtle Lake (Janssen, 1968), and Heikkilla Lake, Sabin Lake, and South Lempia Lake (Björck, 1990). A *Pediastrum* peak is also found associated with the lower part of the late glacial spruce maximum at Wis Bog, a site in Kenosha County, southeast Wisconsin (Huber and Overstreet, 1990; Huber and Rapp, 1992). Fredskild (1973) found a similar sequence of development in several lakes and bogs in Greenland based also on the distribution of *Pediastrum*.

The continued increase in abundance of *Scenedesmus* to its maximum at 210 cm indicates that nutrient influx was high throughout most of this zone. In the uppermost part of Zone GLA-2, *Scenedesmus* declines suddenly indicating a reduction of available nutrients in Gegoka Lake. The three *Scenedesmus* peaks indicate that

Gegoka Lake underwent three periods of hypertrophism in Zone GLA-3. Two more periods of hypertrophism are indicated by *Scenedesmus* peaks in Zone GLA-4.

Apparently, the first period of hypertrophism in Zone GLA-4 was shorter-lived than the second.

The apparent periods of hypertrophism indicated by *Scenedesmus* may be attributed to several factors. Fire in the catchment basin may result in increased erosion and nutrient loading of the lake. Lakes may be very sensitive to disturbances such as fire (Bradbury, 1986). The importance of fire in northeast Minnesota during the past 10,000 years has been demonstrated by charcoal studies (Swain, 1973). Increased residence time of water in the lake rather than increased nutrient availability may also reflect periods of hypertrophism (Whiteside, 1983). Vegetational change in the watershed may affect the nutrient influx into the lake. It is also possible that the fluctuations in *Scenedesmus* may be the result of one or any combination of these factors.

In Zone GLA-5, a reduction in nutrient availability is indicated by the decrease in *Scenedesmus* and other algae taxon. The algae decline may have been caused by the expansion of wild rice and the increase in aquatic vegetation. New phosphorus, needed for algal growth, comes from the water sediment interface of the littoral zone (Hutchinson, 1973). This phosphorus source was probably reduced as wild rice and macrophytic vegetation expanded. Light necessary for photosynthesis by the algae may also have been reduced by the expansion of wild rice. The leaves of wild rice

float on the water surface much of the summer reducing available sunlight to the photic zone.

In Zone GLA-5, an increase in *Gloeotrichia*-type, a blue green algae (Cyanochloronta), nitrogen fixing algae (Van Geel, Coope, and Van Der Hammen, 1989) occurs. A shift in nutrient conditions may have resulted in the increase in *Gloeotrichia*-type algae. *Gloeotrichia*-type algae that can absorb nitrogen gas directly from the atmosphere (Lee, 1980) may have been able to bloom competition-free, as nutrient input to Gegoka Lake declined.

EAST BEARSKIN LAKE: LONG CORE

East Bearskin Lake is located approximately 7 km south of the United States/Canada border in Cook County, Minnesota. The lake is in sections 11, 12, 13, and 14, T64N, R1W and section 7, T64N, R1E of the Hungry Jack Lake and in sections 4, 5, 6, 7, 8, and 9 T64N, R1E of the Crocodile Lake 7.5 minute quadrangles. Coring occurred on 4 March 1992 and a 991-cm long core was retrieved from 5.48 m of water at approximately UTM: 694176,5323265, Zone 15.

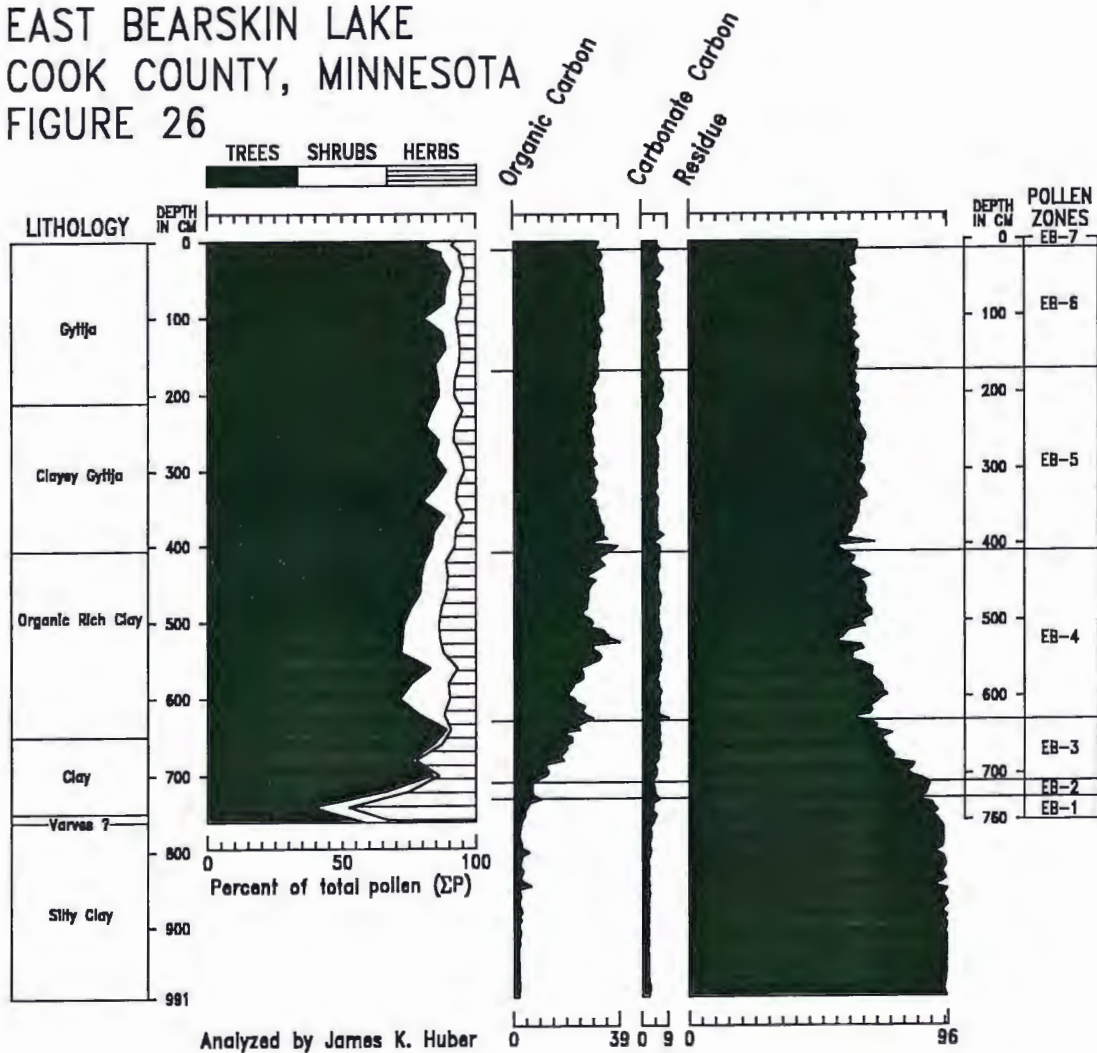
Stratigraphy

The core is composed of eight distinct lithologies: 0-210 cm, dark reddish brown gyttja; 215-316 cm, dark reddish brown clayey gyttja; 316-405 cm, black clayey gyttja; 405-647 cm, very dark gray organic rich clay; 647-712 cm, black clay; 712-750 cm, black silty clay; 750-760 cm, rhythmite (varves ?) black and very dark gray laminae; 760-991 cm, silty clay.

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon ranges from 2% to 39% with the largest value occurring at both 400 cm and 520 cm (Fig. 26). Except for small maxima at 800 cm and 845 cm, organic carbon is less than 5% below 740 cm. Organic carbon gradually increases to 20% between 740 cm and 655 cm and maintains values of greater than 20% to the top of the core except for a minima of 18% at 645 cm. Carbonate content is less than 10% throughout the entire core (Fig. 26).

LOSS-ON-IGNITION PERCENTAGE DIAGRAM EAST BEARSKIN LAKE COOK COUNTY, MINNESOTA FIGURE 26



Pollen Zone EB-1

Zone EB-1 is characterized by NAP of 30% or greater. The prominent NAP types found at East Bearskin Lake are Cyperaceae, *Artemisia*, *Ambrosia*-type, Gramineae and *Equisetum*. Cyperaceae and *Artemisia* both attain maxima of 22% and 10% respectively. *Picea*, *Salix*, *Fraxinus nigra*, *Fraxinus pennsylvanica*/*P. americana*, and Cupressaceae the most AP types. Maxima of *Fraxinus nigra* (17%) and *Fraxinus pennsylvanica*/*P. americana* (7%) occur at 760 cm (Plate 8).

Pollen Zone EB-2

Betula attains a maximum of 14% in Zone EB-2 while *Picea* declines to 11%. *Pinus banksiana*/*P. resinosa* which occurs in only trace amounts in Zone EB-1, begins to increase in Zone EB-2. Cupressaceae reaches its maximum value of 13% in this zone. *Salix* and Cyperaceae are still prominent but declining. *Artemisia*, *Ambrosia*-type, and Gramineae also decline. *Fraxinus nigra*, *Fraxinus pennsylvanica*/*P. americana*, *Quercus*, and *Ulmus* are present at 5% or less (Plate 8).

Pollen Zone EB-3

Picea reaches its maximum abundance of 36% in Zone EB-3. *Pinus banksiana*/*P. resinosa* becomes the dominant taxon at the top of Zone EB-3 (47%). *Betula* declines to almost 3% at 680 cm then increases to 16% at 660 cm. *Fraxinus nigra*, *Fraxinus pennsylvanica*/*P. americana*, *Quercus*, and *Ulmus* all decline in Zone EB-3. Cyperaceae attains a second maxima of 14% at 680 cm then declines.

Artemisia, *Ambrosia*-type, and Gramineae are present at values of less than 5% (Plate 8).

Pollen Zone EB-4

Pinus banksiana/*P. resinosa*, *Betula*, *Alnus*, and *Picea* are the dominant AP types found in Zone EB-4. *Pinus banksiana*/*P. resinosa* maintains values of greater than 30% throughout this zone. *Betula* ranges from 12% to 20%; *Alnus* peaks at 17% at 600 cm then declines to 6% at 420 cm. *Picea* declines to less than 5% at the top of this zone. *Pinus strobus* attains a value of 17% at the top of Zone EB-4. NAP is 14% or less than throughout this zone; Cyperaceae, *Artemisia*, *Ambrosia*-type, Chenopodiaceae/Amaranthaceae, Gramineae, and *Pteridium*-type (bracken fern) are the dominant taxa (Plate 8).

Pollen Zone EB-5

Zone EB-5 is characterized by the transition of *Pinus banksiana*/*P. resinosa* to *Pinus strobus*. *Pinus strobus* increases from 25% to 45% while *Pinus banksiana*/*P. resinosa* declines from 35% to 18%. *Betula* fluctuates between 10% and 20% and *Alnus* ranges from 4% to 11%. *Picea* increases from 1% at the bottom of EB-5 to 6% near the top. *Quercus* is the most dominant deciduous component occurring at values of less than 4%. NAP is low, less than 9%. *Artemisia*, *Ambrosia*-type, and Gramineae are the most prominent NAP taxa with values of less than 3% (Plate 8).

Pollen Zone EB-6

In Zone EB-6, a general increase in *Betula*, *Picea*, Cupressaceae, and *Larix* occurs as *Pinus* declines. *Alnus* values range from 4% to 10%. NAP continues to be low, less than 8%. *Artemisia*, *Ambrosia*-type, and Gramineae are still the most prominent NAP taxa with values of less than 2% (Plate 8).

Pollen Zone EB-7

The rise of *Ambrosia*-type pollen (Plate 8) in the upper sediment of pollen cores in the midwest, associated with deforestation and land clearance by pioneer settlement (Wright, 1971) is small but apparent at the top of Zone EB-7. *Ambrosia*-type pollen increases from 0.6% at 15 cm to 3% at 10 cm and is accompanied by an increase in *Ambrosia*-type pollen concentration from 3,080 grains/cm³ of wet sediment at 15 cm to 24,792 grains/cm³ of wet sediment at 10 cm. *Ambrosia*-type pollen concentration decreases to 8,900 grains/cm³ of wet sediment at 5 cm and to 8,495 grains/cm³ of wet sediment at the top of the core. *Ambrosia*-type pollen concentration maxima indicate deforestation and land clearance by pioneer settlement in the vicinity of the East Bearskin Lake watershed.

Algae Zone EBA-1

In Zone EBA-1, *Botryococcus*, a pioneer species, attains its maximum value of 15.6%. Algae concentrations are very low, 300-16,200 coenobia/cm³ of wet sediment, and only 12 different taxa are present (Plate 9). Dinoflagellate cysts

(dormant, thick-walled cells) also occur, however their paleoecological significance has not yet been determined (Norris and McAndrews, 1970). Blue green algae (Cyanochloronta) of *Gloeotrichia*-type, a nitrogen fixing algae (Van Geel, Coope, and Van Der Hammen, 1989) is also a pioneer taxa. After its initial appearance in the lake, *Gloeotrichia*-type continues to be a consistent component of the algae spectra throughout the rest of the sequence (Plate 9).

Algae Zone EBA-2

Scenedesmus, a colonial green algae (Chlorophycophyta) indicative of elevated nutrient levels (Cronberg, 1982), *Zygnema*-type resting spores, an indicator of mesotrophic habitats, and *Pediastrum Boryanum*, an indicator of lake eutrophication (Cronberg, 1982), are the dominant taxa in Zone EBA-2. *Scenedesmus* (22%) and *Pediastrum Boryanum* (18%) both have maximum at 720 cm. *Zygnema*-type reaches its maximum value of 38% at 660 cm. *Botryococcus* declines less than 5% (Plate 9).

Algae Zone EBA-3

In Zone EBA-3, *Zygnema*-type declines to trace amounts. *Scenedesmus* values increase significantly ranging from 15% to 33%. Values of *Pediastrum Boryanum*, *Gloeotrichia*-type, *Pediastrum integrum*, and *Pediastrum duplex* var. *clathratum* also increase (Plate 9).

Algae Zone EBA-4

Scenedesmus and *Pediastrum Boryanum*, with minor fluctuations, decrease in Zone EBA-4. After a small maximum at the base of this zone, *Gloeotrichia*-type also declines. In Zone EBA-4, there is a major decrease in relative abundance of all the dominant algae taxa (Plate 9)

Discussion

The Compositae-Cyperaceae Assemblage Zone of Cushing (1967) is represented by the pollen spectra from Zone EB-1. This zone is interpreted to represent an open environment, most likely tundra, with occasional stands of spruce or outliers of individual spruce trees. Dwarf willow and juniper probably were present. The relatively high values of *Fraxinus nigra* and *Fraxinus pennsylvanica*/*P. americana* are an anomaly in northeastern Minnesota pollen diagrams for this pollen assemblage zone. At Kylen Lake, *Fraxinus nigra* values reach approximately 10% in the Compositae-Cyperaceae. The abundance of this taxa at Kylen Lake is interpreted as being blown in from long distances from the south (Birks, 1981). At Lempia Lake, relatively high values of *Fraxinus nigra* occur between 12,500 and 11,500 years ago (Björk, 1990), but no interpretation regarding the abundance of ash was made. At Lake of the Clouds, approximately 50 km slightly southwest of East Bearskin Lake, high values of *Fraxinus nigra* also occur. Craig (1972) also attributes the presence of ash to long distance transport.

Zone EB-2 is interpreted as shrub parkland and represents the *Betula-Picea* Assemblage Zone of Cushing (1967). At this time, a forest-tundra of dwarf birch and willow with scattered black and white spruce and juniper probably occurred in the vicinity. At Weber Lake, the type locality for the *Betula-Picea* Assemblage Zone, this zone dates from 10,500 to 10,200 yr B.P. This is the first recorded occurrence of this zone in Cook County.

Picea values decrease as *Pinus* values increase in Zone EB-3. Combined *Picea* and *Pinus* are the most abundant pollen types. Cupressaceae and the deciduous taxa, *Quercus*, *Ulmus*, *Fraxinus*, *Populus*, and *Betula* are also important. The *Ulmus* maximum that occurs as *Pinus* is replacing *Picea*, usually between 10,000 and 9,000 yr B.P. in many mid-western sites (Maher, 1977; Wright, 1968b), occurs in this zone. This zone is interpreted as representing a conifer-hardwood forest and is the *Picea-Pinus* Assemblage Zone of Cushing (1967). The *Picea-Pinus* Assemblage Zone dates from approximately 10,200-9,000 yr B.P. at Weber Lake. The age for the top of this zone at Lake of the Clouds is 9,200 yr B.P. (Craig, 1972).

Zone EB-4 is the *Pinus-Betula-Alnus* Assemblage Zone as defined by Cushing (1967) except that NAP does not increase at the top of the zone and *Abies* does not occur in values of more than 1% throughout the sequence. In Zone EB-4, *Pinus* is the most abundant taxon followed by *Betula* and *Alnus*. Cupressaceae is still important, which indicates its probable presence around the lake in the form of white cedar. The increase in prairie-type taxa found at the top of this zone elsewhere is not evident at East Bearskin Lake. This may be in part because this zone is younger at

the more northerly site. At Lake of the Clouds, this zone dates from 9,200 to 8,300 yr B.P. based on varve counts (Craig, 1972). At Weber Lake, the age of this zone is radiocarbon dated at 9,000 to 7,000 yr B.P. (Fries, 1962). Zone EB-4 is interpreted as representing a mixed conifer-hardwood forest.

During Zone EB-5, a succession from red and/or jack pine to white pine occurs in a mixed conifer-hardwood forest. The migration of *Pinus strobus* into northeastern Minnesota occurs at 7,000 yr B.P. at Lake of the Clouds (Craig, 1972) and at approximately the same time at Jacobson Lake and Weber Lake (Wright and Watts, 1969). At East Bearskin Lake, *Pinus strobus* clearly dominates the *Pinus* pollen profile unlike the *Pinus* profile from Lake of the Clouds (Craig, 1972) for this period of time. Craig (1972) concludes that the greater abundance of *Pinus banksiana*/*P. resinosa* in the *Pinus* pollen profile at Lake of the Clouds supports Wright's (1968b) hypothesis that a refugia for jack and red pine existed northward from Weber Lake during the prairie-period. The *Pinus strobus* pollen profile from East Bearskin Lake indicates that jack and red pine refuge must not have existed much further east than Lake of the Clouds.

The small rise in NAP associated with the expansion of the prairie peninsula and the white pine rise approximately 7,000 years ago does not occur in the East Bearskin Lake pollen percentage profiles. It may be that East Bearskin Lake was too far from the border of the expanded prairie to receive any significant amounts of wind blown prairie pollen.

The increase in abundance of *Picea*, Cupressaceae, and *Larix* in Zone EB-6 indicates that bogs are forming in the bays in East Bearskin Lake, which creates a new habitat for these taxa as part of a mixed conifer-hardwood forest. The increase in *Picea* may not necessarily indicate the formation of bogs but the return of cooler, moister conditions after the Hypsithermal.

The small increase in *Ambrosia*-type percentages and the increase in *Ambrosia*-type concentration in Zone EB-7 is interpreted to reflect deforestation by Euro-American settlers about 1890 (Maher 1977). This zone is commonly found in the upper sediment of pollen cores in the midwest and is associated with deforestation and land clearance by Euro-American settlement (Wright, 1971).

The nonsiliceous algae assemblages associated with the pollen sequence from East Bearskin Lake indicate that the trophic status of the lake has changed over time. Zone EBA-1 represents the initial period of algal colonization in the lake. East Bearskin Lake was oligotrophic in this early stage of development and the algae assemblage is represented by pioneer species. As sediment began to infill the basin, the lake became more eutrophic, which is indicated by the increase in *Scenedesmus*, *Pediastrum Boryanum*, and *Zygnema*-type in Zone EBA-2. The *Pediastrum Boryanum* maximum at the base of EBA-2 correlates with the late glacial *Picea* zone. *Scenedesmus* and/or *Pediastrum* maxima associated with the late glacial spruce zone have been observed at several sites in Minnesota and Wisconsin (Crisman, 1978; Birks, 1981; Janssen, 1968; Björck, 1990; Huber and Overstreet, 1990; Huber and Rapp, 1992) and is interpreted as indicating increased productivity.

The decline of *Zygnema*-type to trace amounts and the increase in *Scenedesmus*, *Pediastrum Boryanum*, *Gloeotrichia*-type, *Pediastrum integrum*, and *Pediastrum duplex* var. *clathratum* indicate a shift in the trophic status and/or water chemistry of East Bearskin Lake. Nutrient influx in EBA-3 is still high, however the shift in the algae assemblage suggests a change in water chemistry or changing environmental and/or limnologic conditions. The decline in algae abundance in Zone EBA-4 indicates a reduction in nutrient availability and that East Bearskin Lake became more oligotrophic.

WILD RICE POLLEN GRAIN SIZE FREQUENCY: REFERENCE SAMPLES

Based on the measurements of 700 hundred reference pollen grains, the average size of a wild rice (*Zizania aquatica*) pollen grain is 35 μm (Table 2). The range on the 700 pollen grains is 28-46 μm . The 90% confidence limits calculated for all the reference grains measured is 28 μm and 41 μm .

TABLE 2. WILD RICE REFERENCE POLLEN GRAIN SIZE DATA.				
Reference Slide Number	Minimum Grain Size μm	Maximum Grain Size μm	Average Grain Size μm	Number of Grains
UMD 699	30	46	39	100
UMD 701	28	42	35	100
UMD 750	28	46	36	100
UMD 751	28	44	33	100
UMD 752	28	42	33	100
UMD 753	28	38	33	100
UMD 754	28	44	34	100
COMBINED	28	46	35	700

The wild rice pollen grain measurement data indicate that there is some variability in grain size with respect to different plants. This may be the result of differing environmental conditions, differences in strains, or some other factor. The size frequencies for each reference slide, the combined frequencies for all pollen grain measurements combined, and 90% confidence limits are plotted in Figure 27.

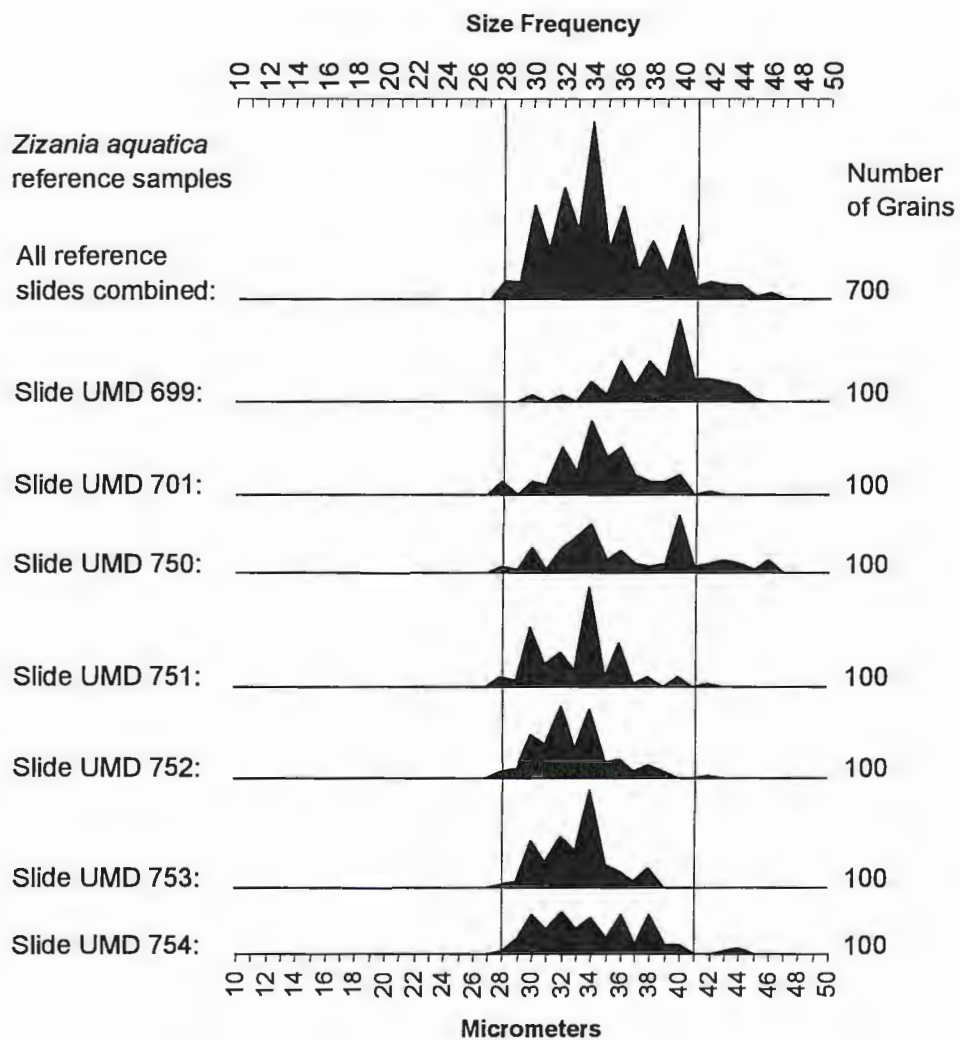


Figure 27. Comparison of *Zizania aquatica* (wild rice) reference slide pollen grain size frequency distribution. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements.

BIG RICE LAKE: SURFACE SAMPLES

Big Rice Lake is considered a very good ricing lake with wild rice covering almost the entire surface of the lake. Four surface samples are available from Big Rice Lake (Fig. 28). The specific location of Big Rice Lake is given in "Big Rice Lake: Long Core." Location data for the surface samples are shown in Table 3.

TABLE 3. BIG RICE LAKE SURFACE SAMPLE LOCATION DATA.					
Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
C-1	537914	5282524	Livingstone	1.00	31 January 1984
C-2	539665	5283498	Livingstone	0.33	31 January 1984
C-3	537359	5282002	Livingstone	1.32	9 March 1989
H-1	538377	5282649	Hongve	1.14	13 October 1988

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon ranges from 37% to 47%. Carbonate content occurs in values of 4% to 7% (Fig. 29).

Pollen Spectra

Gramineae dominates the pollen spectra of the four samples with values ranging from 34% to 41%. *Pinus* is the most abundant tree pollen type followed by *Betula*. *Picea* and *Alnus* is also important (Fig. 30). Gramineae pollen grain size distributions and grass pollen percentages of the surface samples from Big Rice Lake are shown in Figure 31.

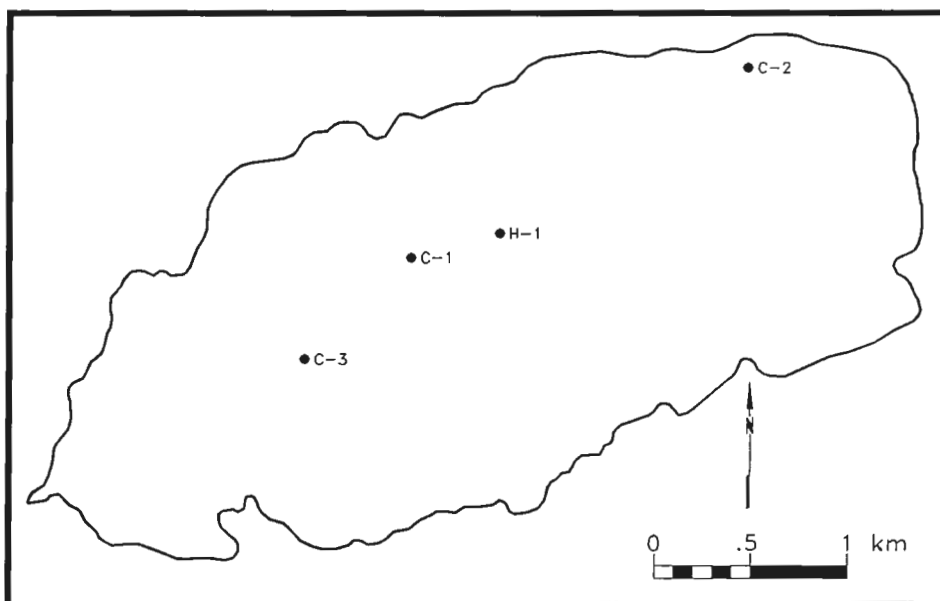
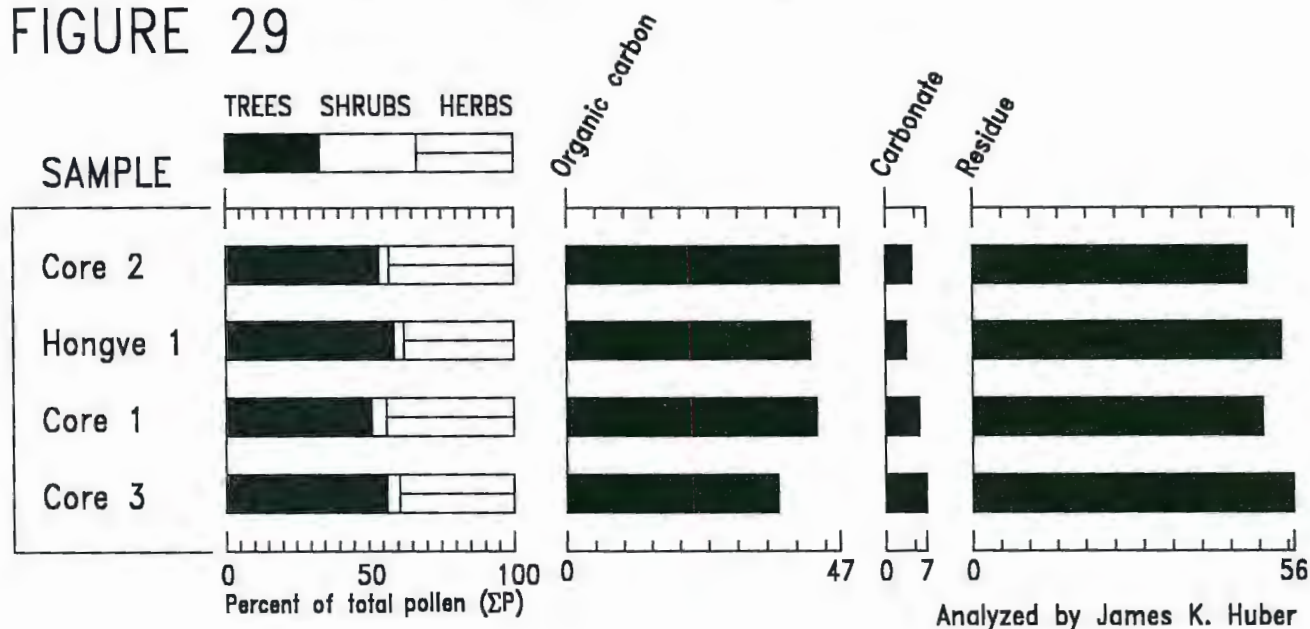


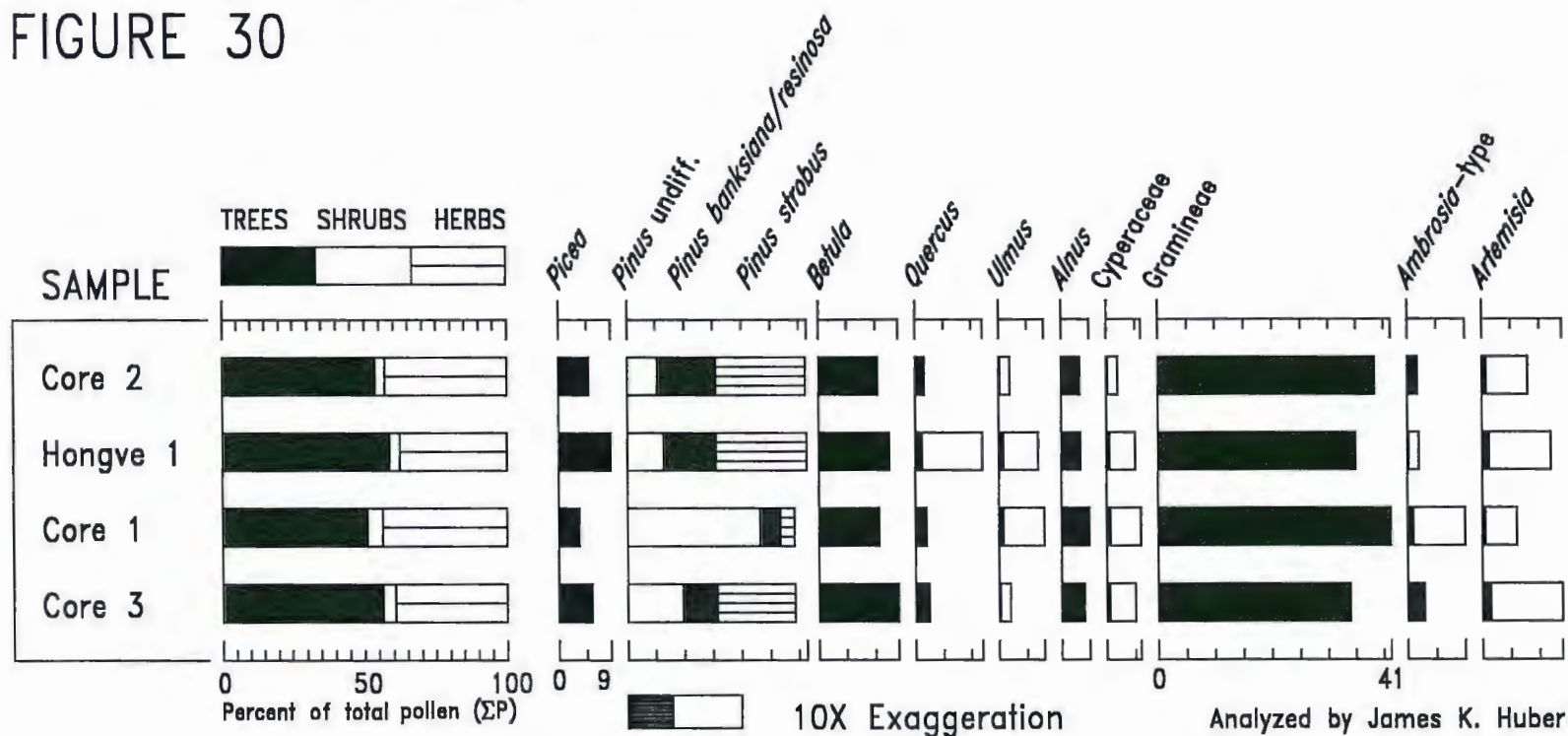
Figure 28. Map of approximate sample locations at Big Rice Lake.

LOSS-ON-IGNITION PERCENTAGE DIAGRAM BIG RICE LAKE SURFACE SAMPLES ST. LOUIS COUNTY, MINNESOTA FIGURE 29



POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA BIG RICE LAKE SURFACE SAMPLES ST. LOUIS COUNTY, MINNESOTA FIGURE 30

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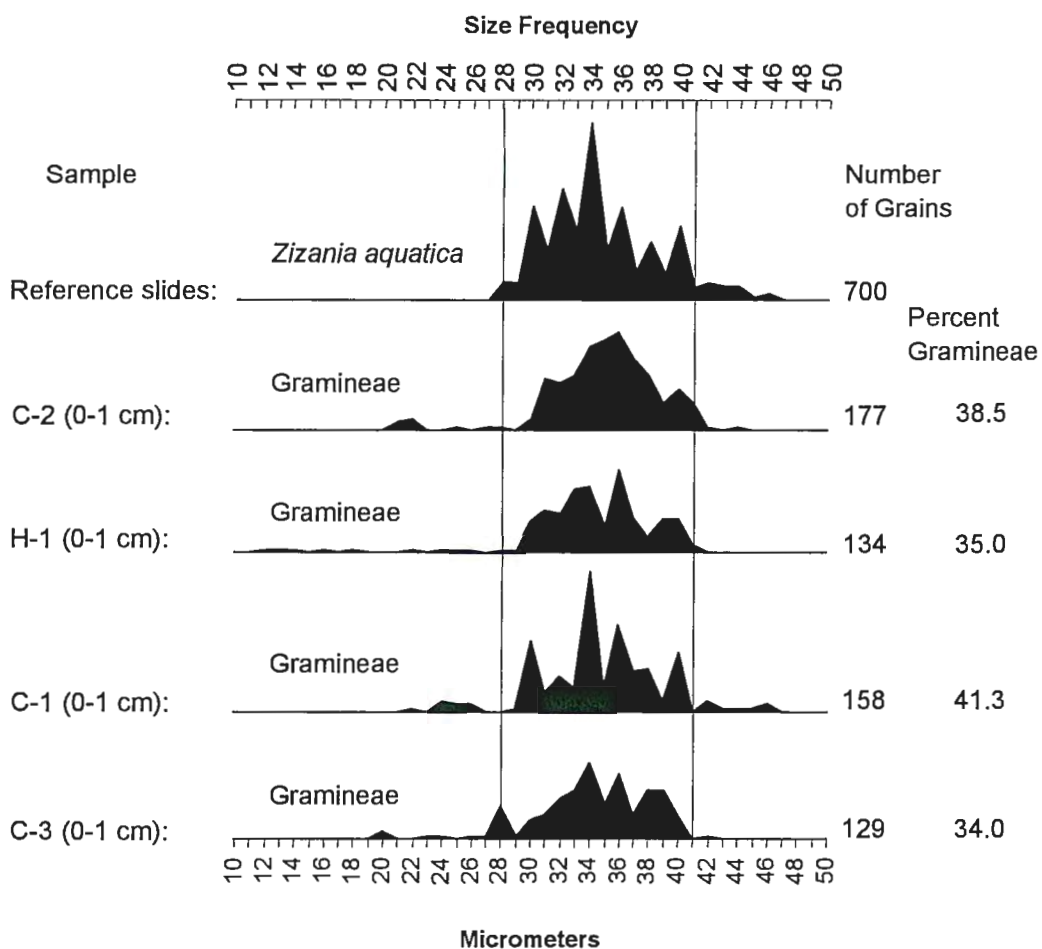


Figure 31. Comparison *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from Big Rice Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

CRAMER LAKE: SURFACE SAMPLES

Cramer lake in section 19, T58N, R6W of the Cramer 7.5' quadrangle.

Cramer Lake is considered a fair wild rice lake (1854 Authority, 2000) and was approximately 70% covered with wild rice at the time of sampling. Four surface samples were recovered from Cramer Lake (Fig. 32). Location data for the surface samples are shown in Table 4.

TABLE 4. CRAMER LAKE SURFACE SAMPLE LOCATION DATA.					
Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
H-1	643203	5264743	Hongve	0.92	4 September 2000
H-2	643356	5264637	Hongve	0.86	4 September 2000
H-3	643424	5264556	Hongve	0.95	4 September 2000
H-4	643457	5264474	Hongve	1.00	4 September 2000

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon values are consistent ranging from 34% to 38%. Carbonate content occurs in values of 4% to 8% (Fig. 33) and is highest for the sample nearest to the shoreline (Fig. 32).

Pollen Spectra

Gramineae values range from 19% to 28% and dominate the pollen spectra of the four samples. *Pinus*, *Betula*, *Picea*, *Alnus*, and *Ambrosia*-type are also important (Fig, 34). Gramineae pollen grain size distributions and grass pollen percentages of the surface samples from Cramer Lake are shown in Figure 35.

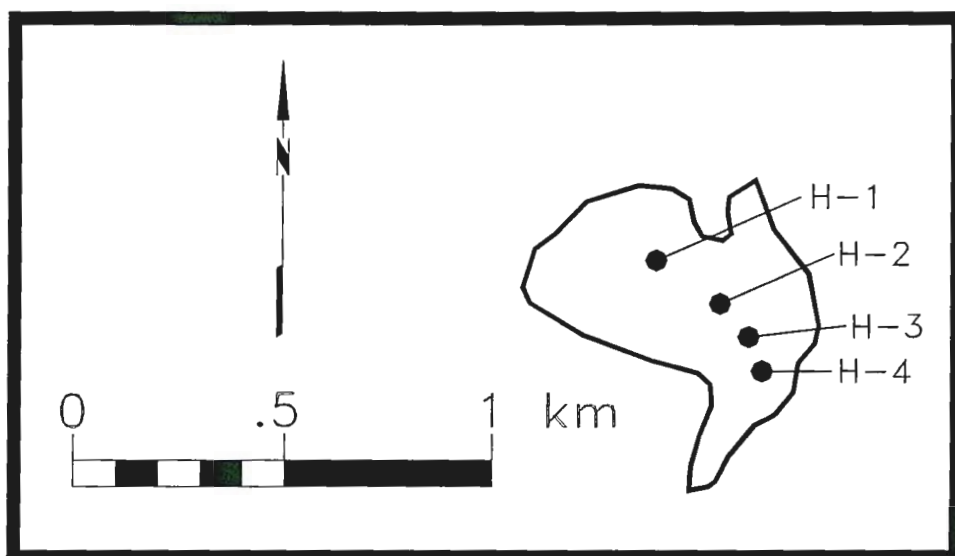
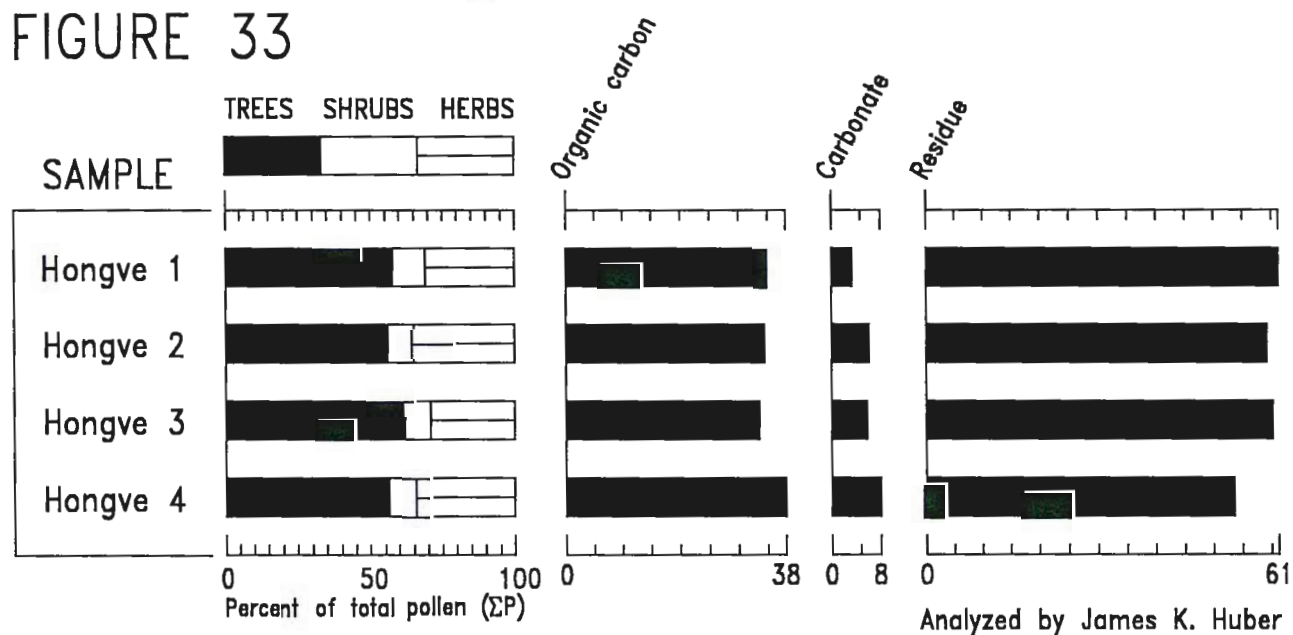


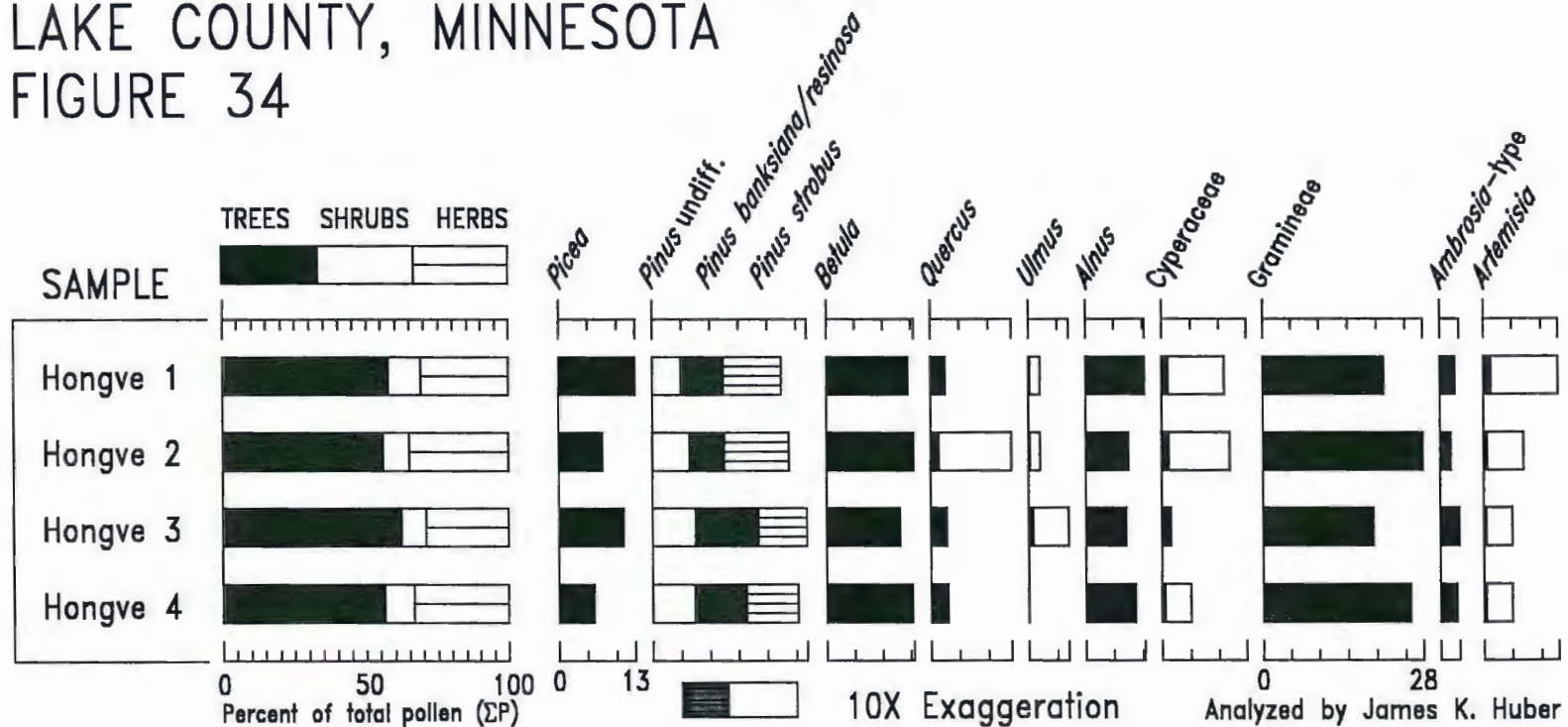
Figure 32. Map of approximate sample locations at Cramer Lake.

LOSS-ON-IGNITION PERCENTAGE CRAMER LAKE SURFACE SAMPLES LAKE COUNTY, MINNESOTA FIGURE 33



POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA CRAMER LAKE SURFACE SAMPLES LAKE COUNTY, MINNESOTA FIGURE 34

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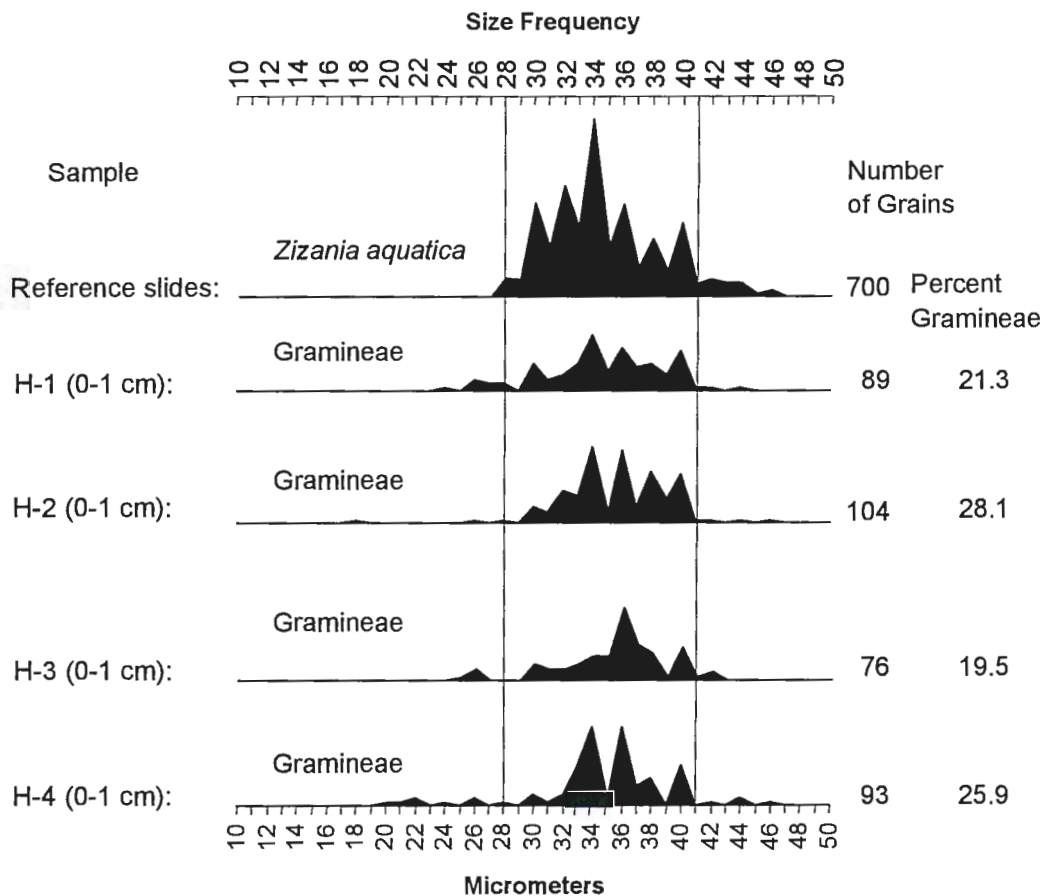


Figure 35. Comparison of *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from Cramer Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

DUMBBELL LAKE: SURFACE SAMPLES

Dumbbell Lake is located in sections 6 and 7, T59N, R7W and section 1, T59N, R8W of the Isabella 7.5' quadrangle and section 6, T59N, R7W, section 1, T59N, R8W, and section 31, T60N, R7W of the Sawbill Landing 7.5' quadrangle. Although Dumbbell Lake is a relatively large lake (193 ha), wild rice only occurs in some of the bays and is not a very heavy stand. Dumbbell Lake is rated as a fair wild rice lake by the 1854 Authority (2000). Six surface samples were recovered from Dumbbell Lake (Fig. 36). Samples H-1, H-2, and H-4 are from within the wild rice stand, samples H-3 and H-5 are from just outside the wild rice stand, and sample H-6 represents the deeper, non wild rice area of the lake (Fig. 36). Location data for the surface samples are shown in Table 5.

TABLE 5. DUMBBELL LAKE SURFACE SAMPLE LOCATION DATA.					
Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
H-1	630801	5274952	Hongve	0.45	4 September 2000
H-2	630705	5274951	Hongve	0.65	4 September 2000
H-3	630553	7274946	Hongve	1.70	4 September 2000
H-4	630363	5275331	Hongve	0.76	4 September 2000
H-5	630380	5275194	Hongve	2.10	4 September 2000
H-6	629974	5274989	Hongve	9.20	4 September 2000

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon values at Dumbbell Lake range from 52% to 76% (Fig. 37). The highest organic carbon values are from within or very close to the wild rice stands. The lowest organic carbon values are from the mouth of the bay and the center part of the basin in deep water (Fig. 36). At the mouth of the bay large boulders occur and the sediment is much rockier. Carbonate content occurs in values of 2% to 7% (Fig. 37) with the highest carbonate in the central, deep water locality (Fig. 36).

Pollen Spectra

Arboreal pollen dominates the pollen spectra from Dumbbell Lake. Total *Pinus* fluctuate considerably (30-52%) from site to site, while *Betula*, *Picea*, and *Alnus* values fairly stable (Fig. 38). Gramineae values are, for the most part, low (0.5-14%). The highest Gramineae values are from within the current rice stand. Surprisingly, the highest Gramineae value (sample H-2) is not from current area of densest wild rice, sample H-1 is. Most of the Gramineae pollen grains fall within the 90% confidence limits for wild rice reference samples. However, three of the four Gramineae grains from the central, deep water sample (H-6) fall outside the 90% confidence limits established for the wild rice reference slides (Fig. 39).

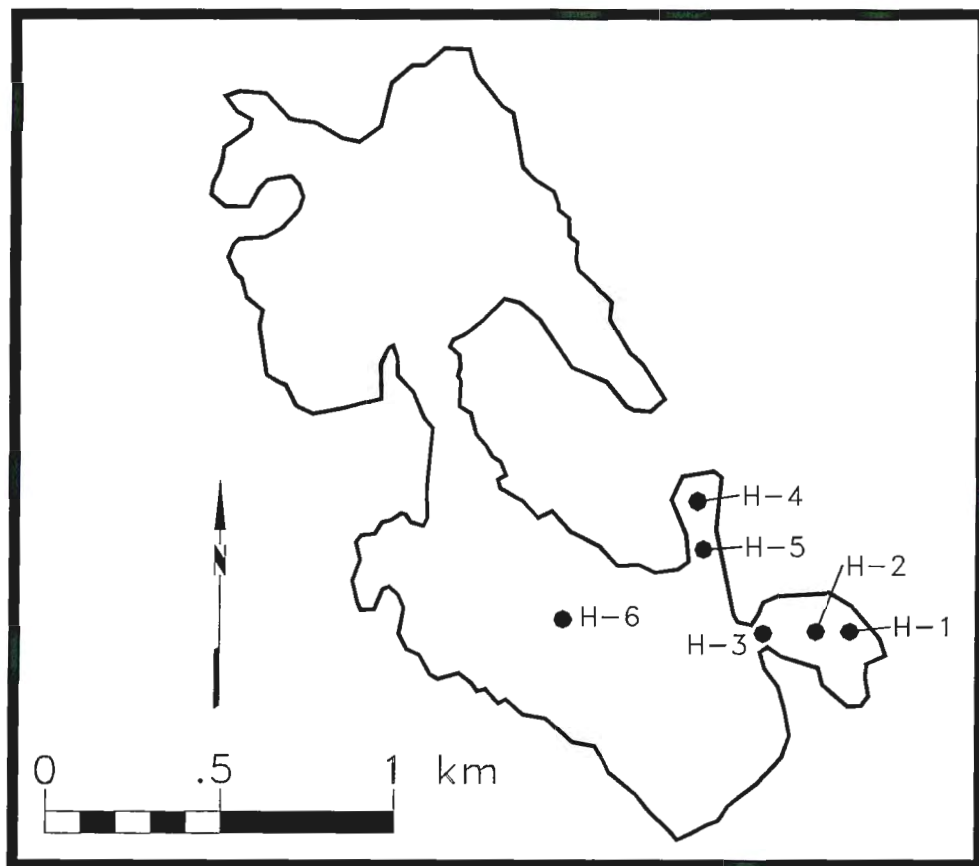
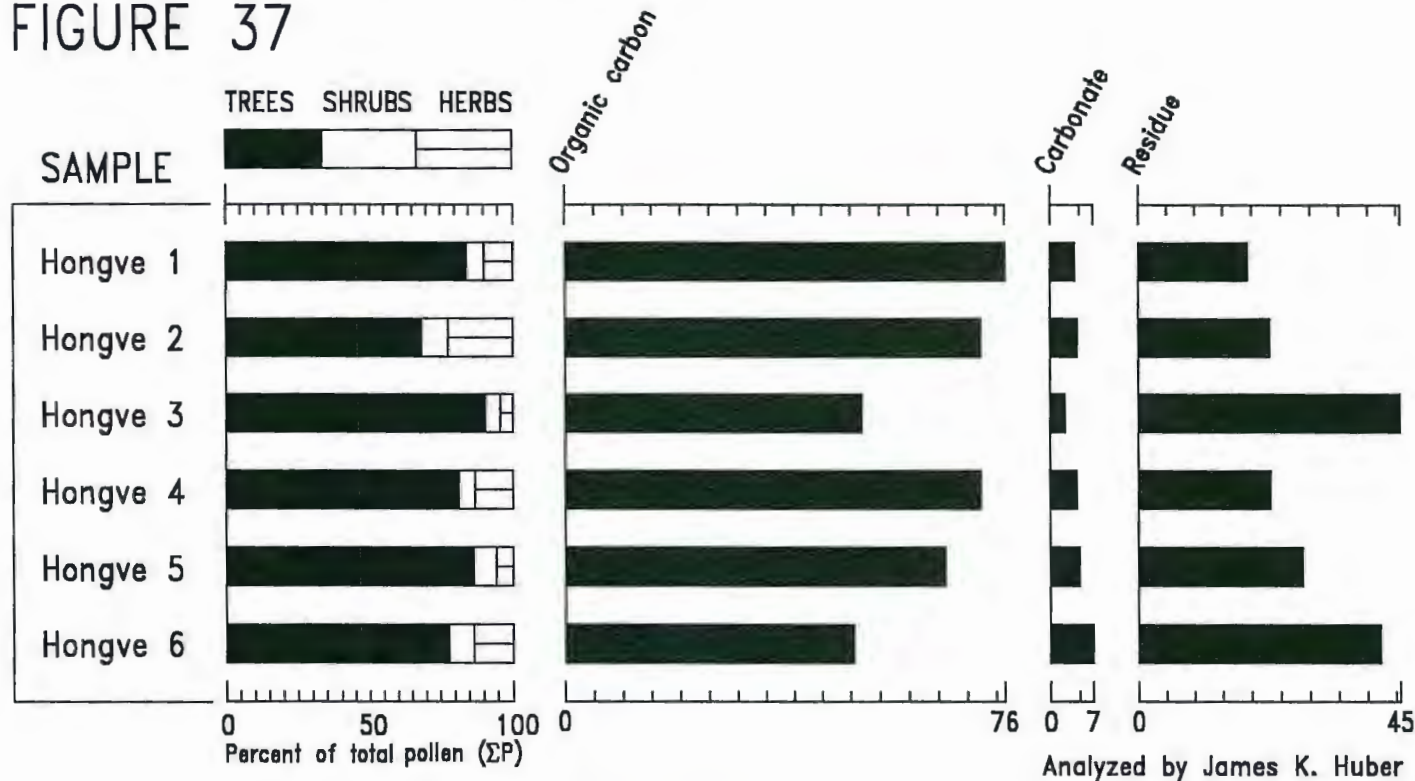


Figure 36. Map of approximate sample locations at Dumbbell Lake.

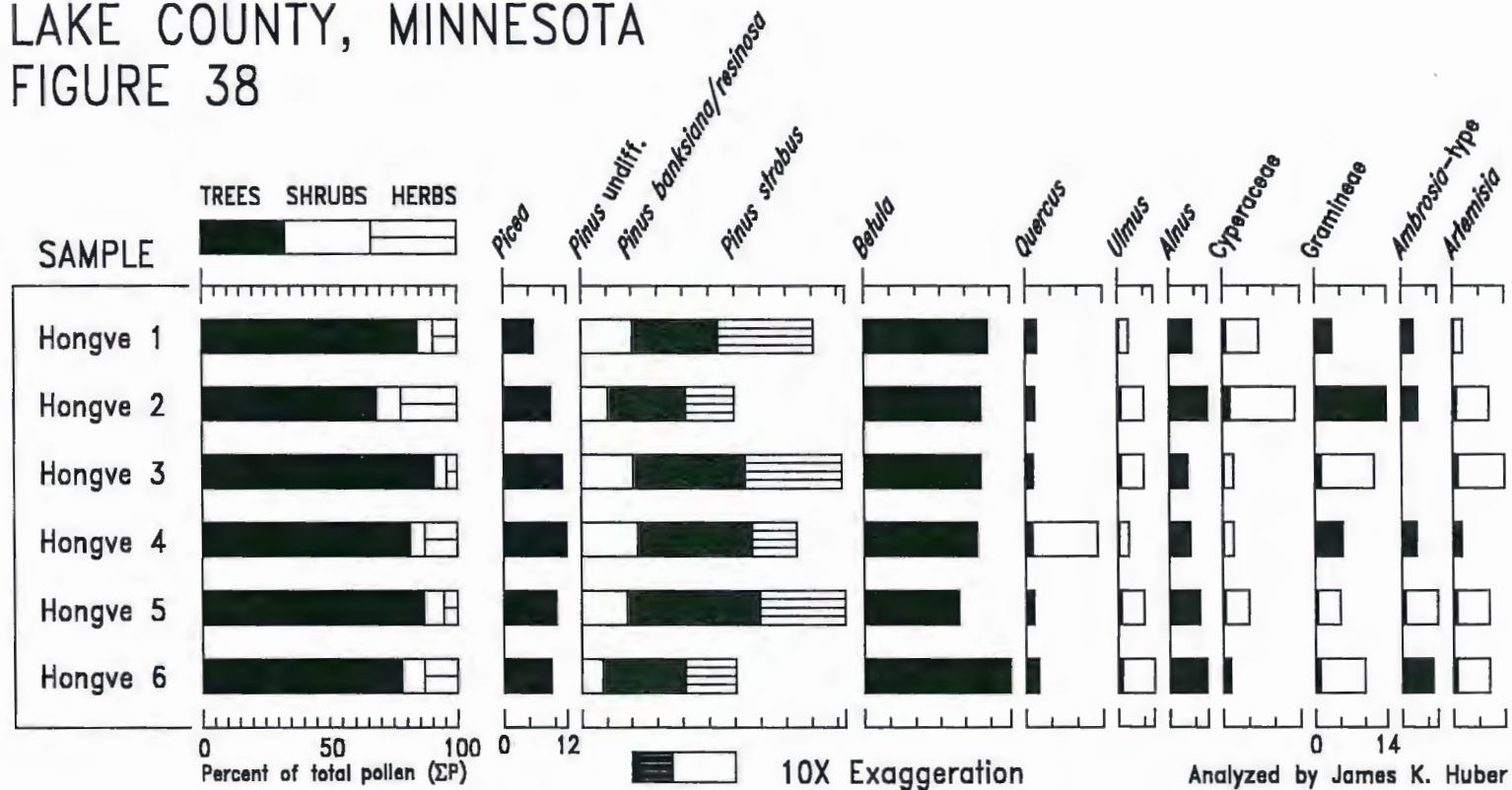
LOSS-ON-IGNITION PERCENTAGE DIAGRAM DUMBELL LAKE SURFACE SAMPLES LAKE COUNTY, MINNESOTA FIGURE 37

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POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
DUMBELL LAKE SURFACE SAMPLES
LAKE COUNTY, MINNESOTA
FIGURE 38

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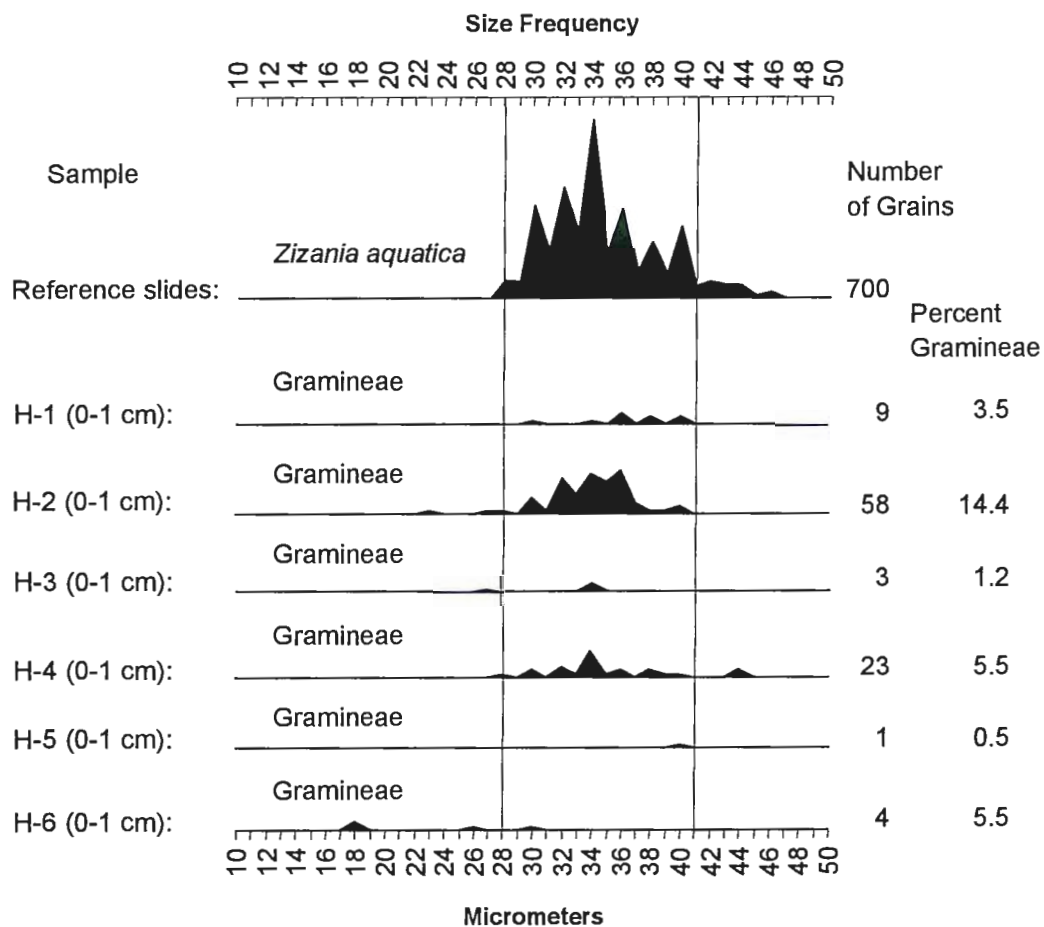


Figure 39. Comparison of *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from Dumbbell Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

GEGOKA LAKE: SURFACE SAMPLES

Gegoka Lake is considered a fair ricing lake (1854 Authority, 2000). Wild rice is most abundant in the northern basin, where it covers approximately 70% of the water's surface. Approximately 50% of the middle basin is covered by wild rice. The southern basin contains very little wild rice (Fig. 40). However, the wild rice stands as a whole are relatively thin. The densest stands of wild rice occur near samples H-7 and H-10. Although little wild rice occurs in the southern basin, the bay where sample H-10 was retrieved contains a small, fairly dense stand of wild rice. The wild rice found in this bay comprises most of the wild rice found in the southern basin. For Gegoka Lake, nine surface samples are available (Fig. 40). The specific location of Gegoka Lake is given in "Gegoka Lake: Long Core." Location data for the surface samples are shown in Table 6.

TABLE 6. GEGOKA LAKE SURFACE SAMPLE LOCATION DATA.					
Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
C-1	614212	5271741	Livingstone	1.44	2 October 1992
H-3	614250	5271626	Hongve	1.20	4 September 2000
H-4	614140	5271738	Hongve	1.35	4 September 2000
H-5	613717	5271589	Hongve	1.40	4 September 2000
H-6	613887	5271400	Hongve	1.61	4 September 2000
H-7	614204	5271104	Hongve	0.83	4 September 2000
H-8	613750	5271284	Hongve	1.24	4 September 2000
H-9	613508	5270691	Hongve	2.46	4 September 2000
H-10	613492	5270451	Hongve	1.13	4 September 2000

Loss-On-Ignition of Organic Carbon and Carbonate

At Gegoka Lake, organic carbon values range from 32.5% to 50.5% (Fig. 41). The highest organic carbon values (samples H-7 & H-10) are from within the two densest wild rice stands currently found on the lake. The organic carbon values of the other seven samples are very similar (32.5-35.5%). Carbonate content occurs in values of 4% to 9% (Fig. 41).

Pollen Spectra

The pollen spectra from Gegoka Lake is dominated by arboreal pollen. Total *Pinus* (39-53%), *Picea* (8-15%), *Betula* (7-9%), and *Alnus* (4-10%) fluctuate from site to site, while Gramineae values range from 2% to 14% (Fig. 42). The two highest Gramineae values (samples H-7 & H-10) occur in what is currently the densest stands of wild rice. The lowest Gramineae value (sample H-9) occurs in the deeper open portion of the southern basin (Fig. 40). Only two of the eight Gramineae pollen grains from the deeper open water sample (H-9) fall within the 90% confidence limits established for the wild rice reference slides (Fig. 43).

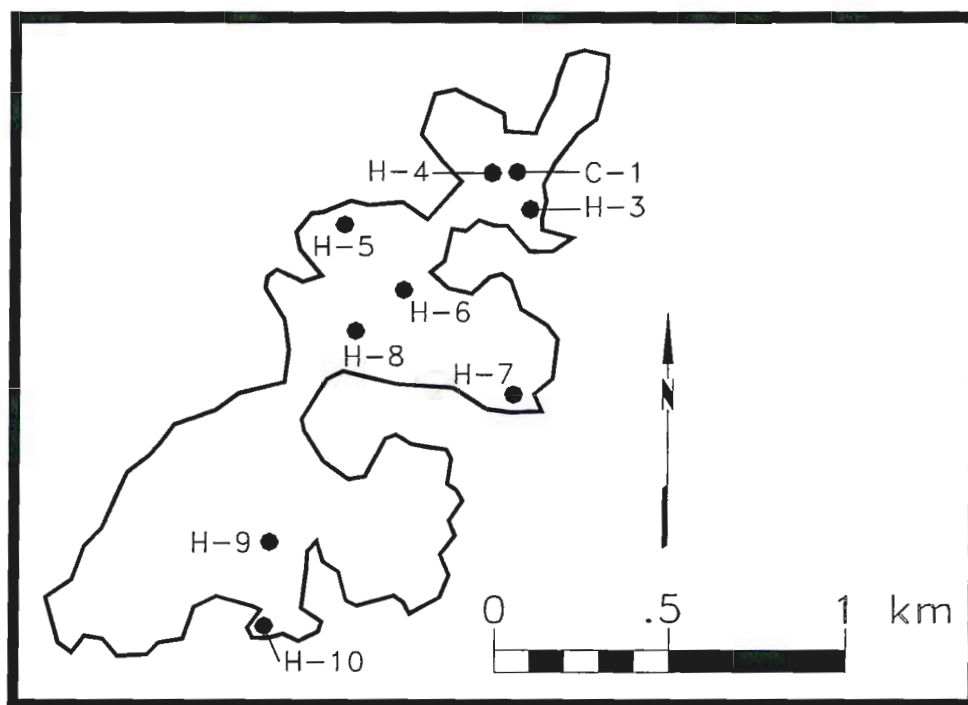
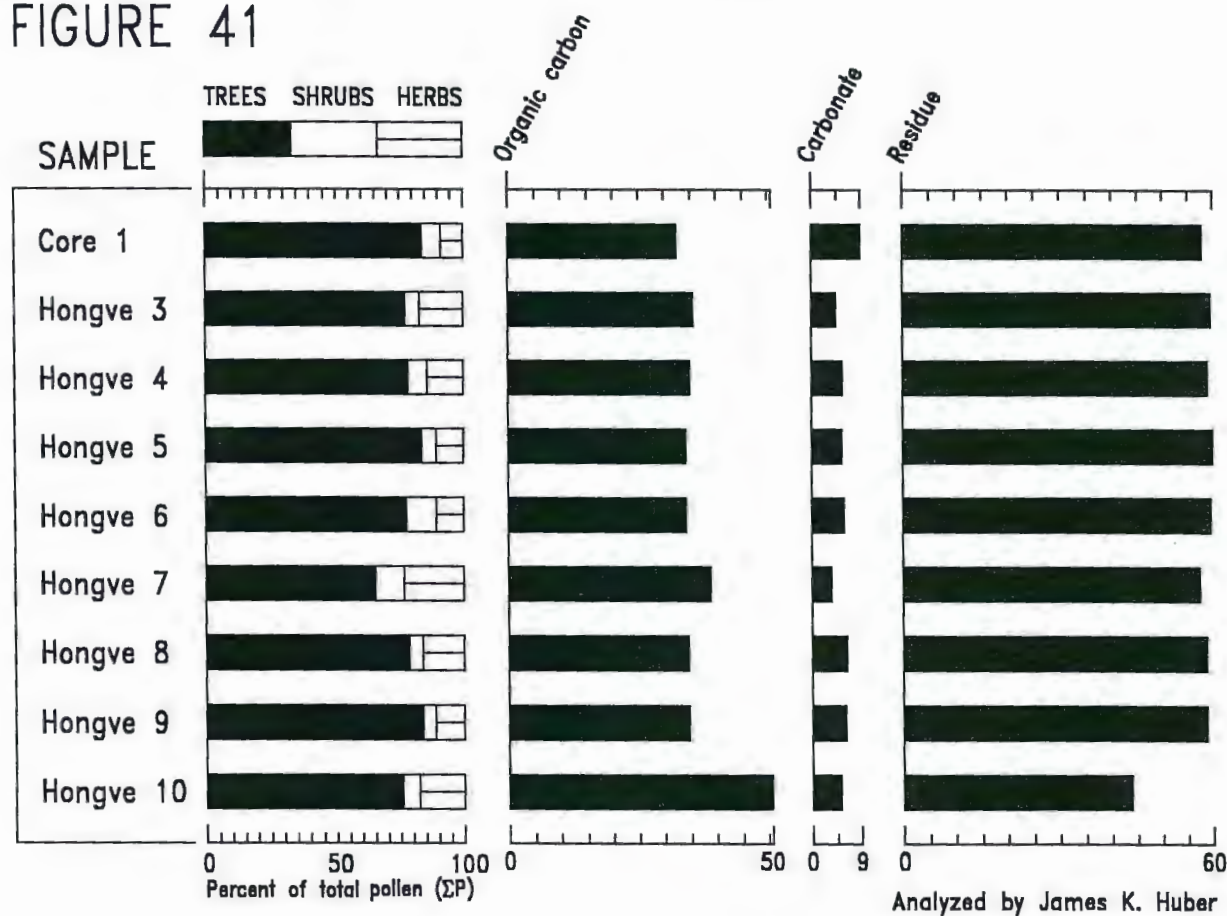
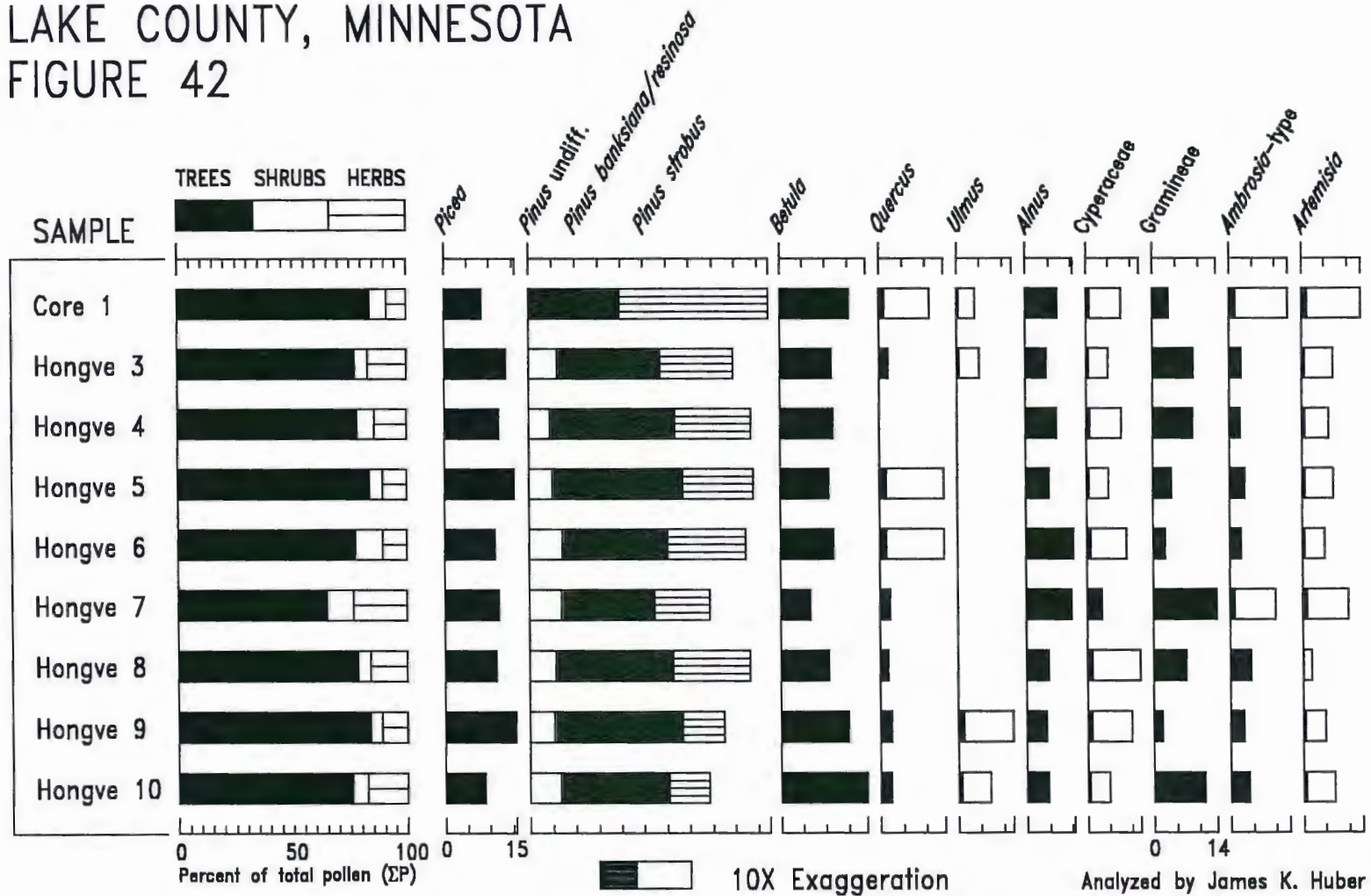


Figure 40. Map of approximate sample locations at Gegoka Lake.

LOSS-ON-IGNITION PERCENTAGE DIAGRAM GEGOKA LAKE SURFACE SAMPLES LAKE COUNTY, MINNESOTA FIGURE 41



POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA GEGOKA LAKE SURFACE SAMPLES LAKE COUNTY, MINNESOTA FIGURE 42



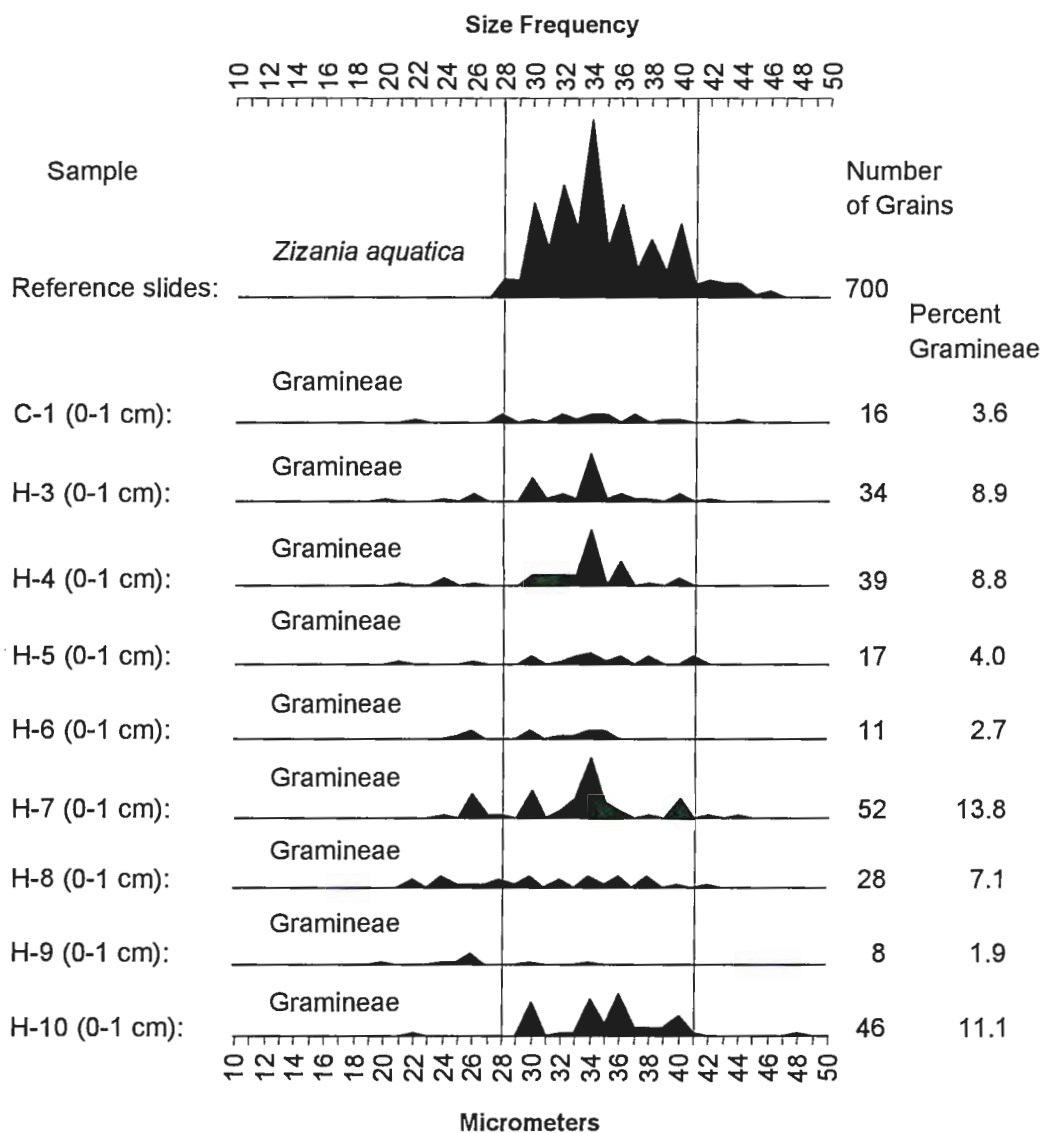


Figure 43. Comparison of *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from Gegoka Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

PERCH LAKE: SURFACE SAMPLES

Perch Lake is usually an excellent ricing lake. Currently wild rice is most abundant and densest in the southwest part of the lake. Wild rice becomes less dense to the northeast and is almost nonexistent in the northeastern basin past the narrows (Fig. 44). Eight surface samples were collected from Perch Lake (Fig. 44). Perch Lake is located in section 6, T48N, R18W, section 1, T48N, R19W, sections 29, 30, 31, T49N, R18W, and section 36, T49N, R19W of the Sawyer 7.5' quadrangle. Location data for the surface samples are shown in Table 7.

TABLE 7. PERCH LAKE SURFACE SAMPLE LOCATION DATA.					
Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
H-1	526121	5171590	Hongve	4.30	3 September 2000
H-2	525807	5171272	Hongve	1.51	3 September 2000
H-3	525756	5170933	Hongve	0.33	3 September 2000
H-4	525681	5170682	Hongve	0.56	3 September 2000
H-5	525431	5170501	Hongve	0.65	3 September 2000
H-6	525126	5170326	Hongve	0.61	3 September 2000
H-7	524613	5169726	Hongve	0.42	3 September 2000
H-8	524265	5169321	Hongve	1.00	3 September 2000

Loss-On-Ignition of Organic Carbon and Carbonate

At Perch Lake, organic carbon values range from 50% to 58% (Fig. 45). The lowest organic carbon value (H-8) is from within the densest wild rice stands currently found on the lake (Fig. 44). Carbonate content occurs in values of 5% to 7% (Fig. 45).

Pollen Spectra

In the pollen spectra from Perch Lake, samples H-1 and H-2 are dominated by arboreal pollen. Gramineae values for samples H-1 and H-2 are 7% and 17% respectively (Fig. 46) and were recovered in the area of the lake with the least wild rice. Nonarboreal pollen types dominate samples H-3 through H-8. Gramineae values for these samples range from 47% to 68% (Fig. 46). The samples having the highest Gramineae values are not from the area of the lake supporting the densest wild rice. Gramineae pollen grain size distributions and grass pollen percentages of the surface samples from Perch Lake are shown in Figure 47.

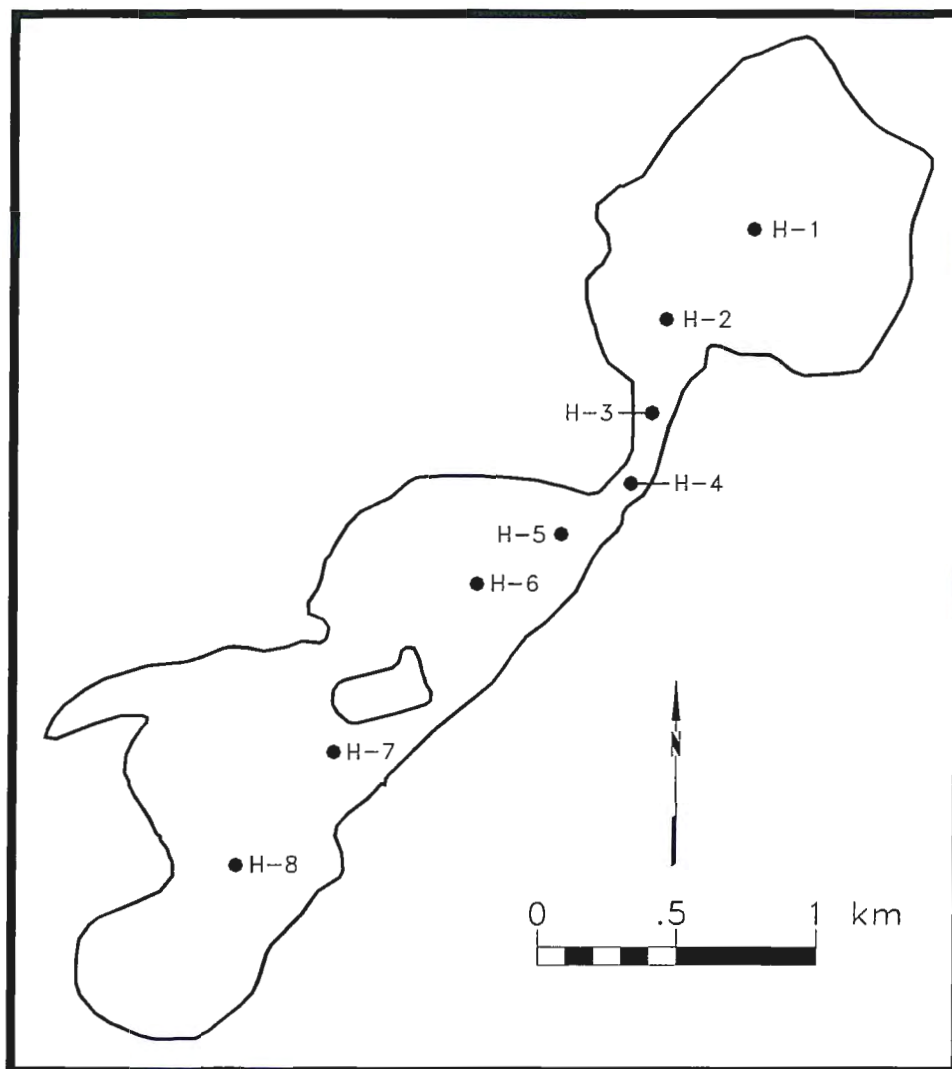
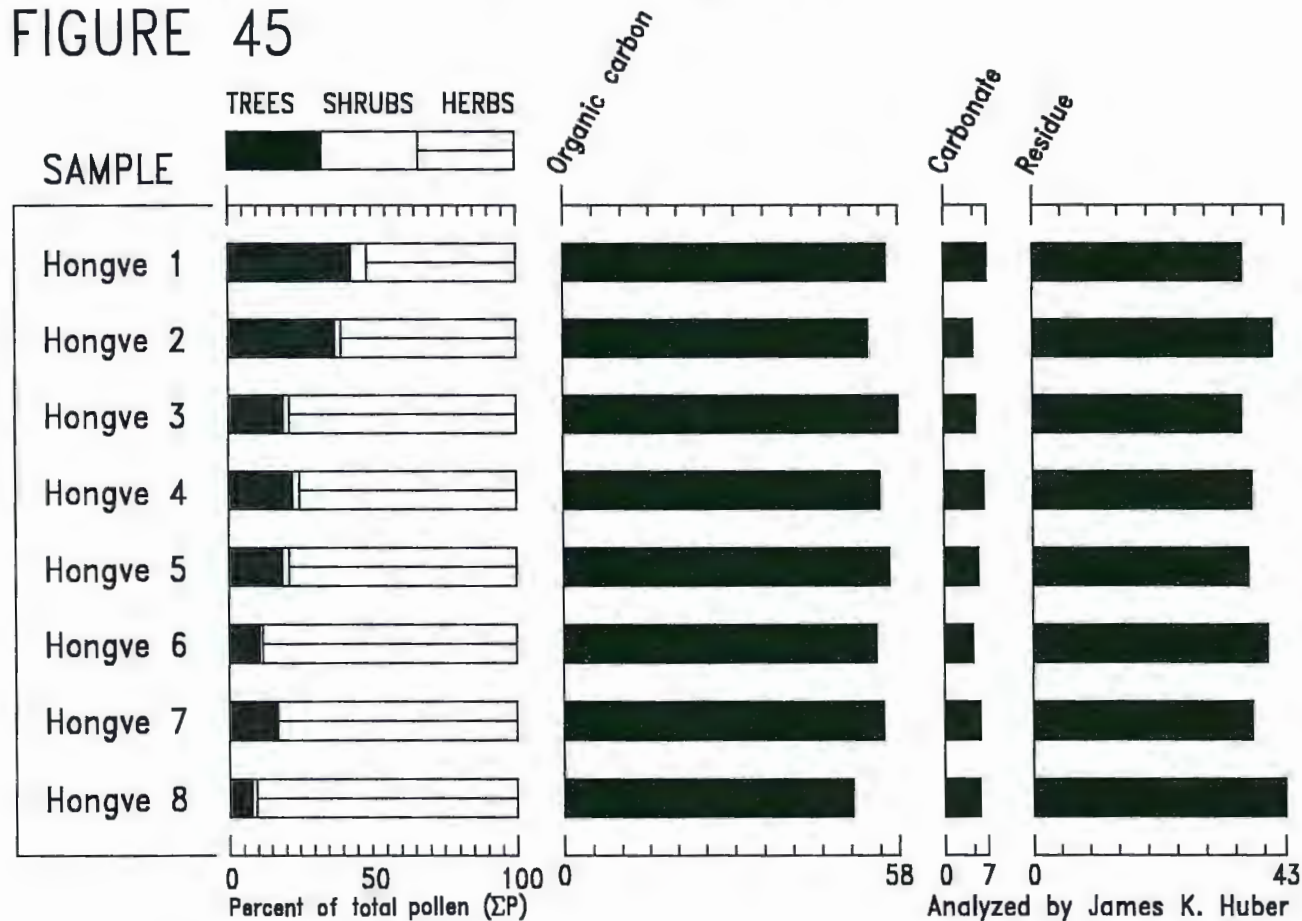


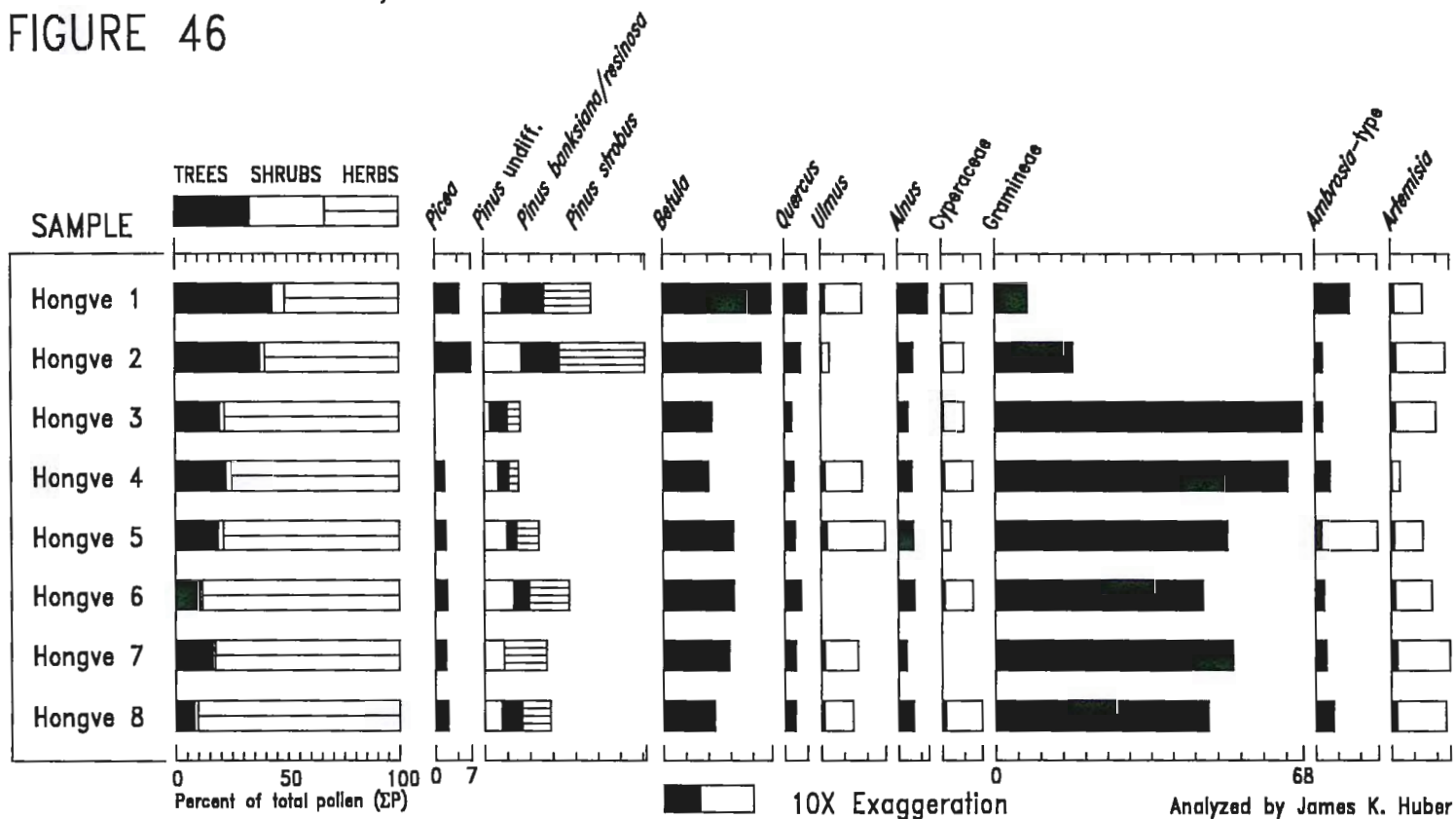
Figure 44. Map of approximate sample locations at Perch Lake.

LOSS-ON-IGNITION PERCENTAGE DIAGRAM PERCH LAKE SURFACE SAMPLES CARLTON COUNTY, MINNESOTA FIGURE 45



POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
 PERCH LAKE SURFACE SAMPLES
 CARLTON COUNTY, MINNESOTA
 FIGURE 46

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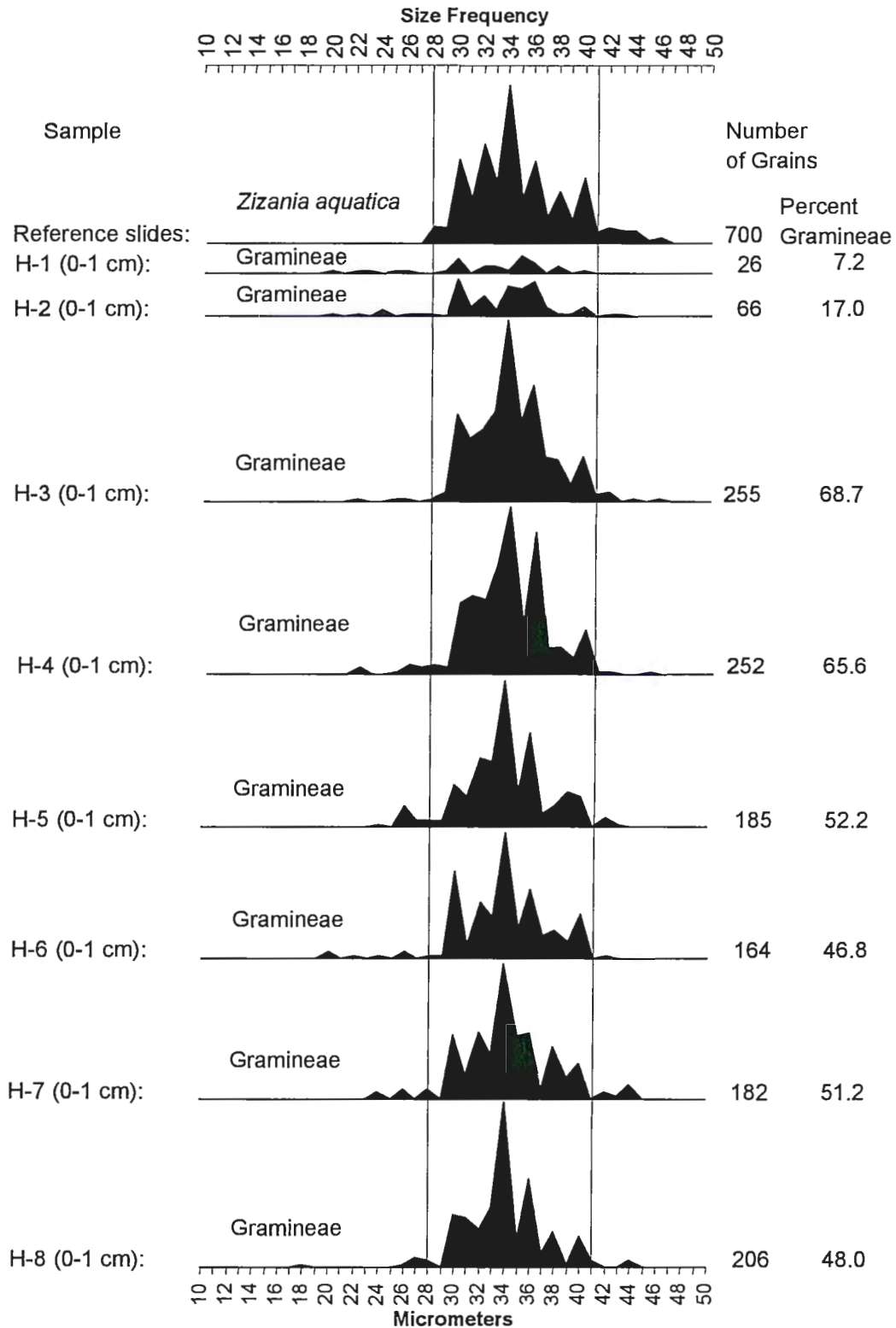


Figure 47. Comparison of *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from Perch Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice grain size measurements. Gramineae pollen percentages are also shown.

RICE PORTAGE LAKE: SURFACE SAMPLES

Rice Portage Lake is located in sections 25 and 26, T49N, R19W of the Sawyer 7.5' quadrangle. Currently the entire lake is covered with a very dense stand of wild rice. It is an excellent lake for wild ricing. Three surface samples were collected from eastern end of the lake (Fig. 48). At the time the surface samples were collected the wild rice was too dense to paddle through. Location data for the surface samples are shown in Table 8.

TABLE 8. RICE PORTAGE LAKE SURFACE SAMPLE LOCATION DATA.					
Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
H-1	523789	5171418	Hongve	0.82	3 September 2000
H-2	523931	5171517	Hongve	0.44	3 September 2000
H-3	524059	5171614	Hongve	0.41	3 September 2000

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon values range from 46% to 49% at Rice Portage Lake.

Carbonate content values range from 3% to 5% (Fig. 49).

Pollen Spectra

Gramineae values range from 50% to 60% and dominate the pollen spectra at Rice Portage Lake. *Picea*, *Pinus*, *Betula*, and *Quercus* are the most abundant arboreal taxa (Fig. 50). Gramineae pollen grain size distributions and grass pollen percentages for the surface samples from Rice Portage Lake are shown in Figure 51.

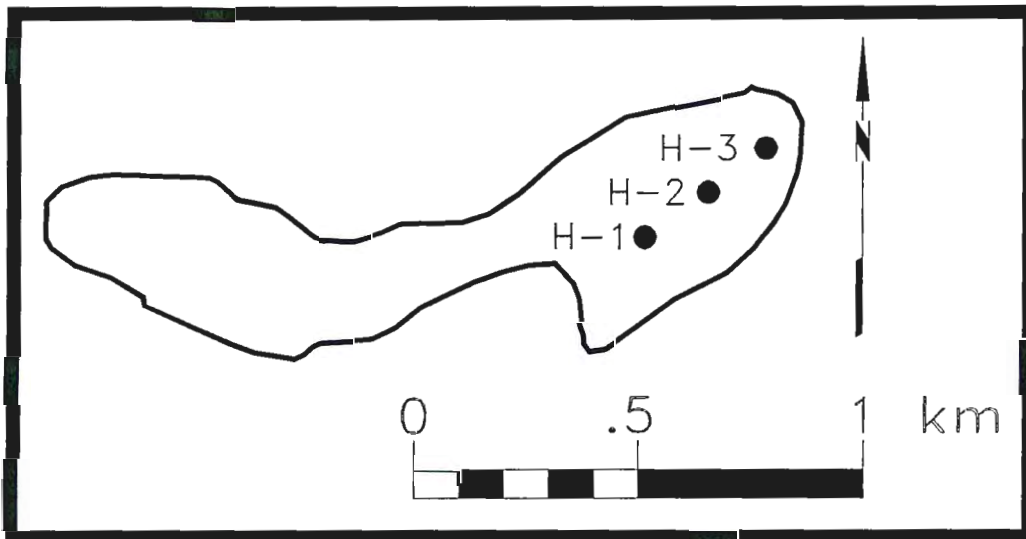
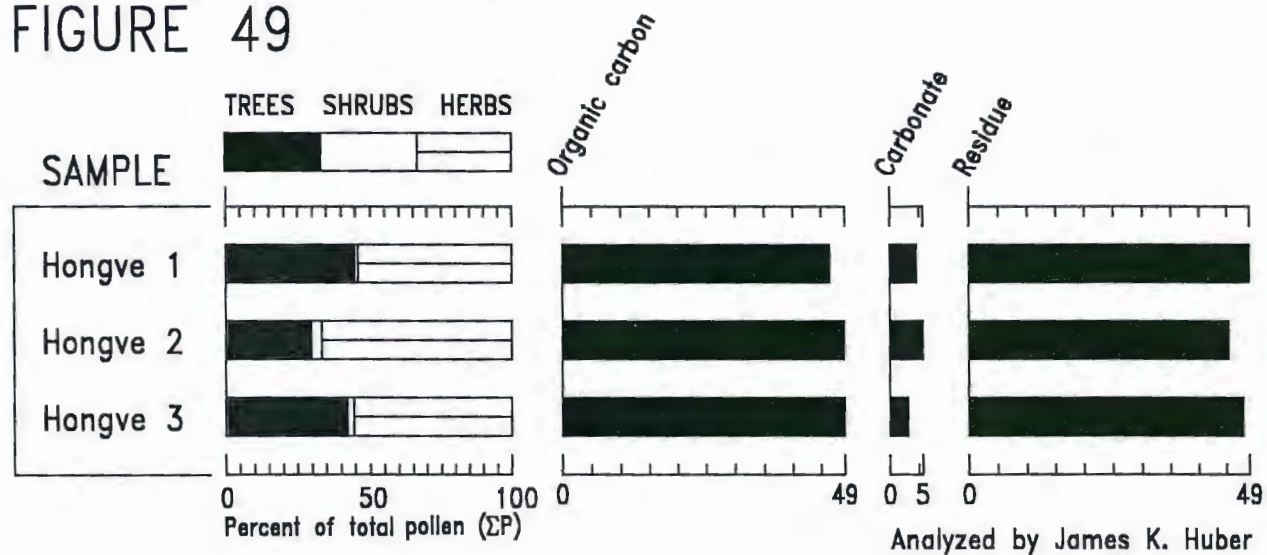
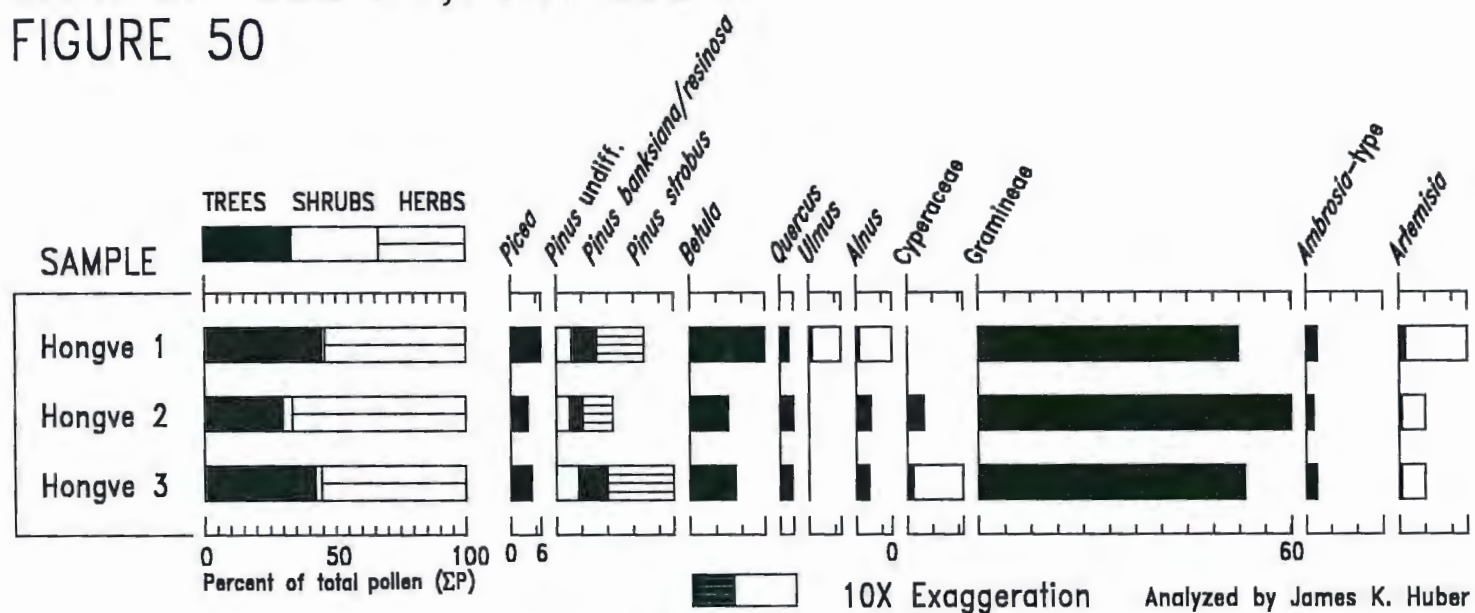


Figure 48. Map of approximate sample locations at Rice Portage Lake.

LOSS-ON-IGNITION PERCENTAGE RICE PORTAGE LAKE SURFACE SAMPLES CARLTON COUNTY, MINNESOTA FIGURE 49



POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
 RICE PORTAGE LAKE SURFACE SAMPLES
 CARLTON COUNTY, MINNESOTA
 FIGURE 50



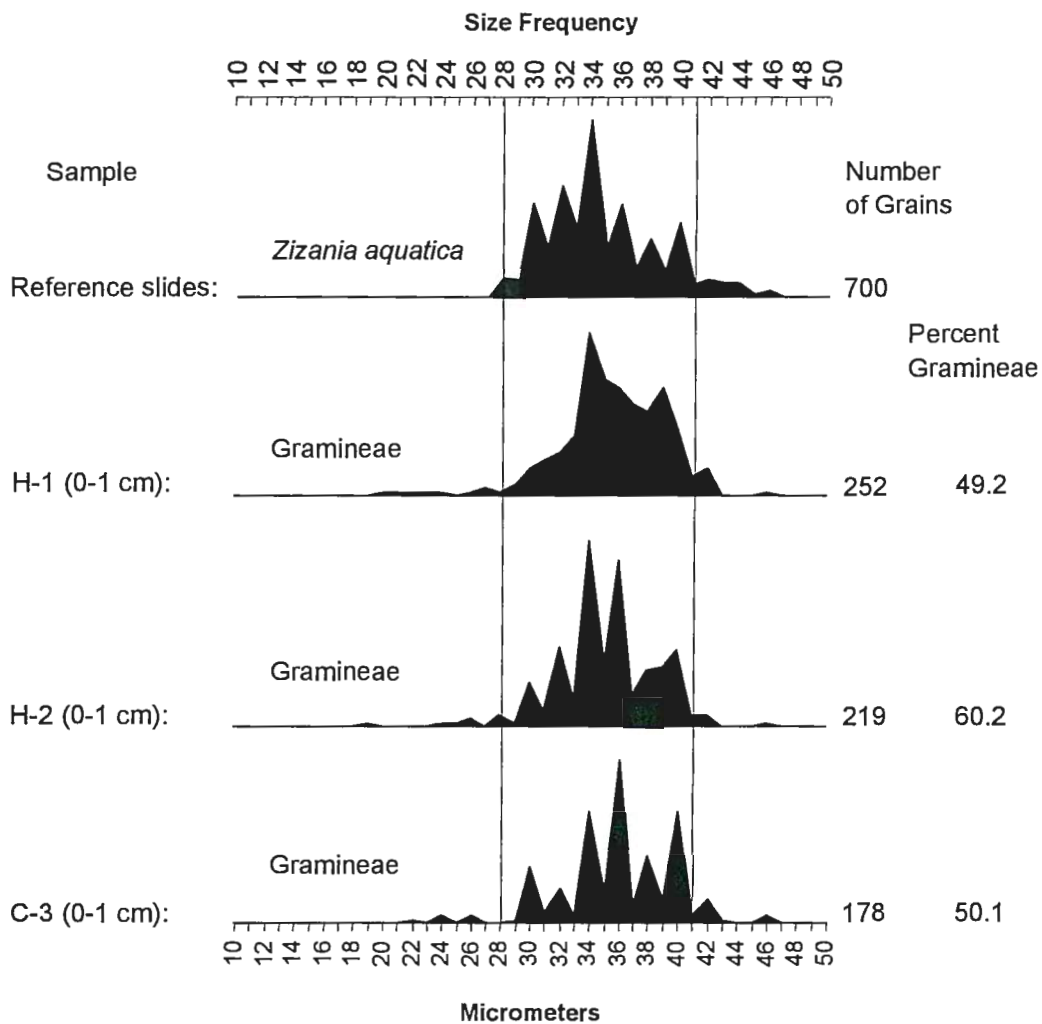


Figure 51. Comparison of *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from Rice Portage Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

ROUND ISLAND LAKE: SURFACE SAMPLES

Round Island Lake is considered a good ricing lake (1854 Authority, 2000). The most abundant and densest wild rice is currently found in the northwest part of the lake. Wild rice becomes less dense to the south and east (Fig. 52). At Round Island Lake, four surface samples were collected (Fig. 52). Round Island Lake is located in section 12, T59N, R8W of the Isabella 7.5' quadrangle. Location data for the surface samples are shown in Table 9.

TABLE 9. ROUND ISLAND LAKE SURFACE SAMPLE LOCATION DATA.					
Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
H-1	628295	5274608	Hongve	0.62	4 September 2000
H-2	628384	5274553	Hongve	0.85	4 September 2000
H-3	628475	5274455	Hongve	1.11	4 September 2000
H-4	628463	5274327	Hongve	1.53	4 September 2000

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon values range from 58% to 60% at Round Island Lake and carbonate content values range from 4% to 6% (Fig. 53). The highest organic carbon value (H-1) is from within the densest wild rice stand currently found on the lake (Fig. 52).

Pollen Spectra

The pollen spectra from Round Island Lake is dominated by arboreal pollen with *Picea*, *Pinus*, *Betula*, and *Alnus* being the most prominent (Fig. 54). Gramineae values range from 15% to 33%. The two samples with the lowest Gramineae values are from the densest and the thinnest wild rice areas in the lake. Sample H-1 comes from the densest wild rice area and sample H-4 from the thinnest (Fig. 52). Figure 55 shows the Gramineae pollen grain size distributions and grass pollen percentages for the surface samples from Round Island Lake.

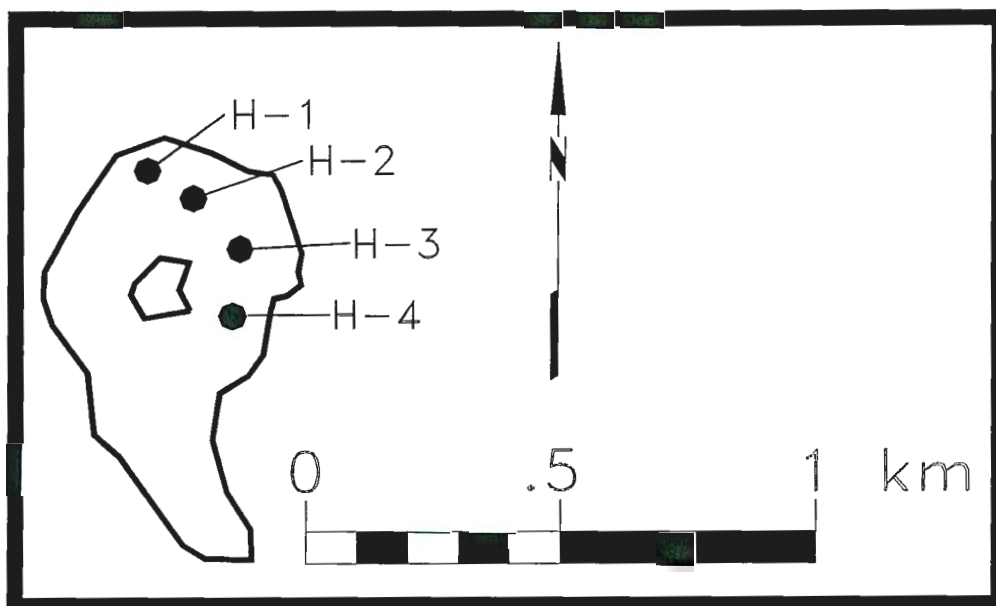
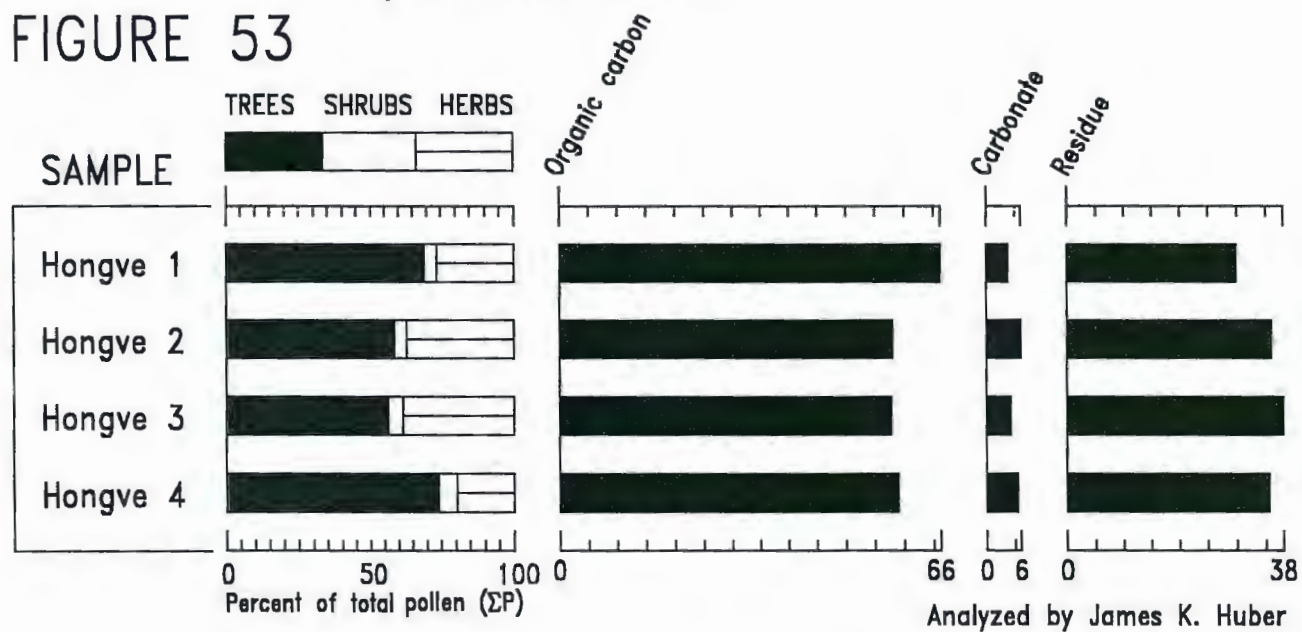


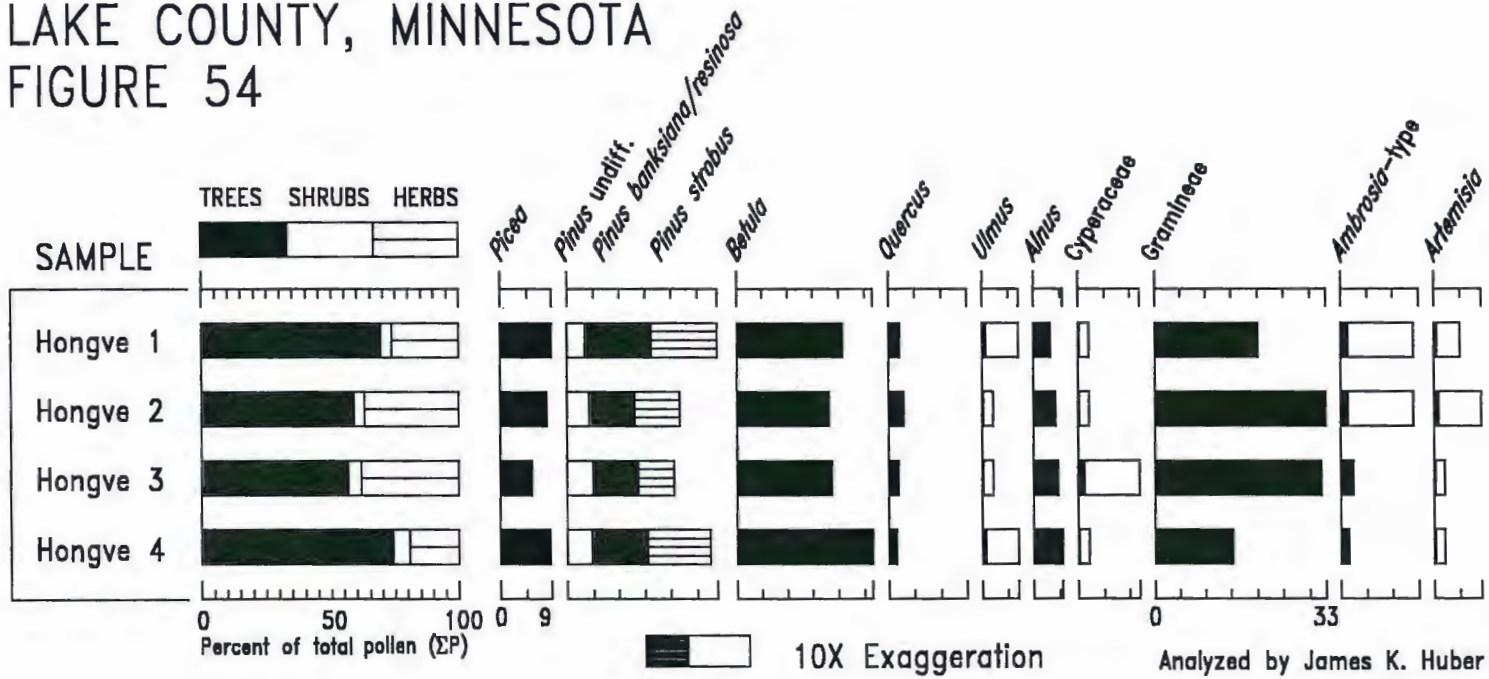
Figure 52. Map of approximate sample locations at Round Island Lake.

LOSS-ON-IGNITION PERCENTAGE DIAGRAM
 ROUND ISLAND LAKE SURFACE SAMPLES
 LAKE COUNTY, MINNESOTA
 FIGURE 53



POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
 ROUND ISLAND LAKE SURFACE SAMPLES
 LAKE COUNTY, MINNESOTA
 FIGURE 54

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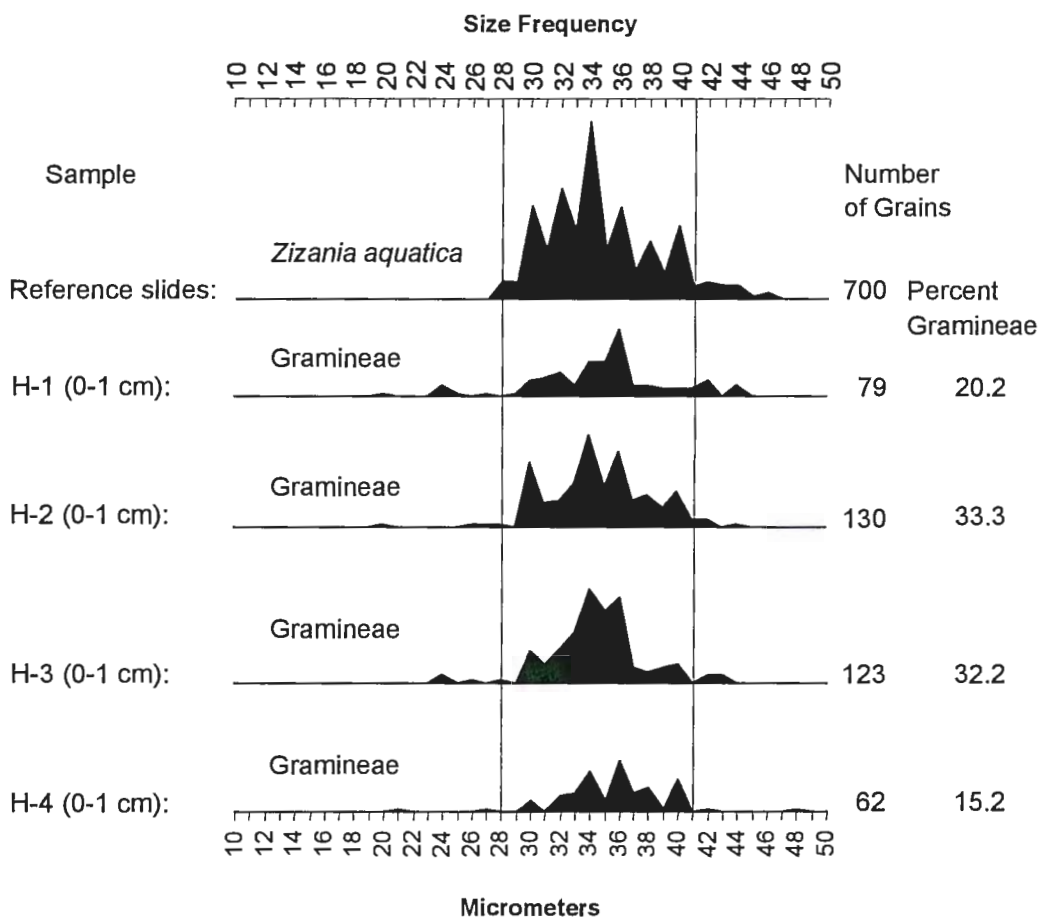


Figure 55. Comparison *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from Round Island Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

SHANNON LAKE: SURFACE SAMPLES

Shannon Lake has wild rice covering approximately one-tenth of its surface. Wild rice occurs in the shallows along the shore and in the bays, inlet, and outlet. Four surface samples were collected from the southern one-half of the lake (Fig. 56). The specific location of Shannon Lake is given in "Shannon Lake: Long Core." Location data for the surface samples are shown in Table 10.

TABLE 10. SHANNON LAKE SURFACE SAMPLE LOCATION DATA.					
Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
C-1	502376	5274495	Livingstone	2.29	5 August 1987
C-2	502192	5274614	Livingstone	3.68	5 August 1987
C-3	502126	5274880	Livingstone	5.33	9 September 1989
H-1	502217	5274380	Hongve	2.32	23 October 1988

Loss-On-Ignition of Organic Carbon and Carbonate

At Shannon Lake, organic carbon values range from 15% to 21% (Fig. 57). Organic carbon content of the surface sediments increases toward the center of the lake (Fig. 56). Carbonate content decreases toward the center of the lake with values increasing from 2% to 4% (Fig. 57).

Pollen Spectra

Picea, *Pinus*, *Betula*, and *Alnus* dominate the Shannon Lake pollen spectra. Gramineae values for the four surface sediment samples are very similar, ranging from 6% to 8% (Fig. 58). The Gramineae pollen grain size distributions and grass pollen percentages for the Shannon Lake surface samples are shown in Figure 59.

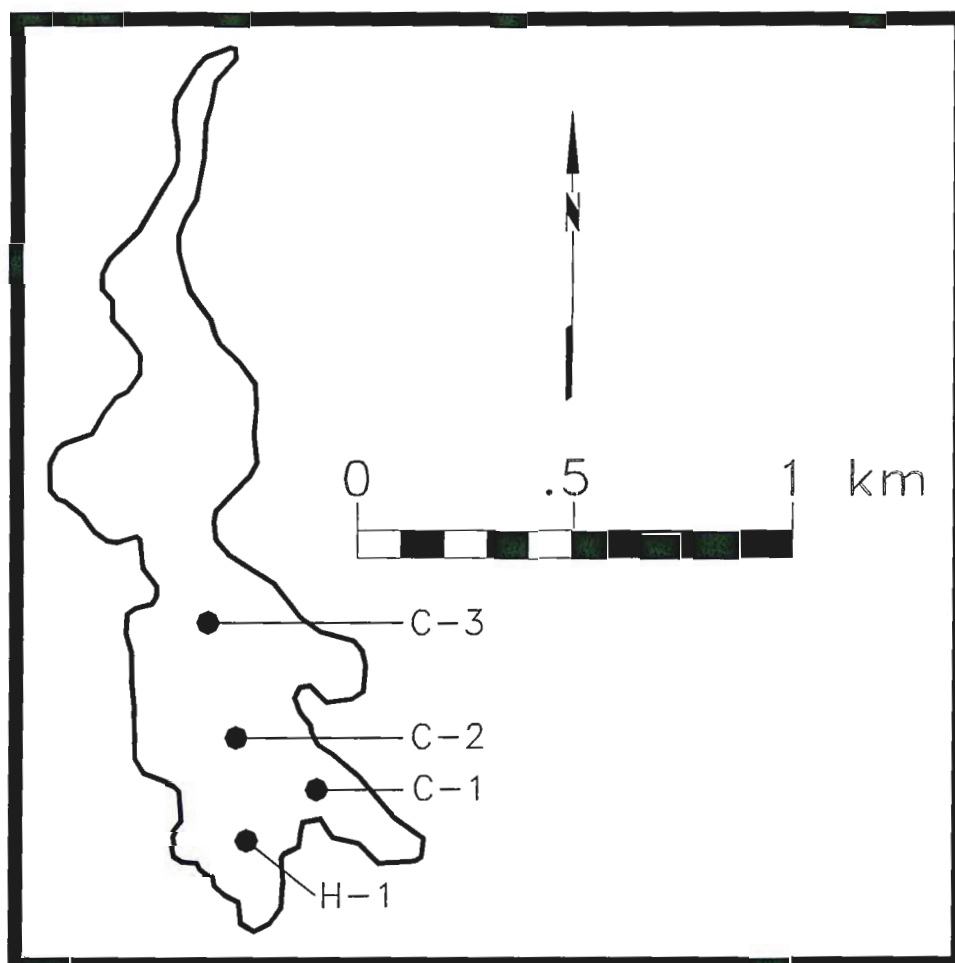
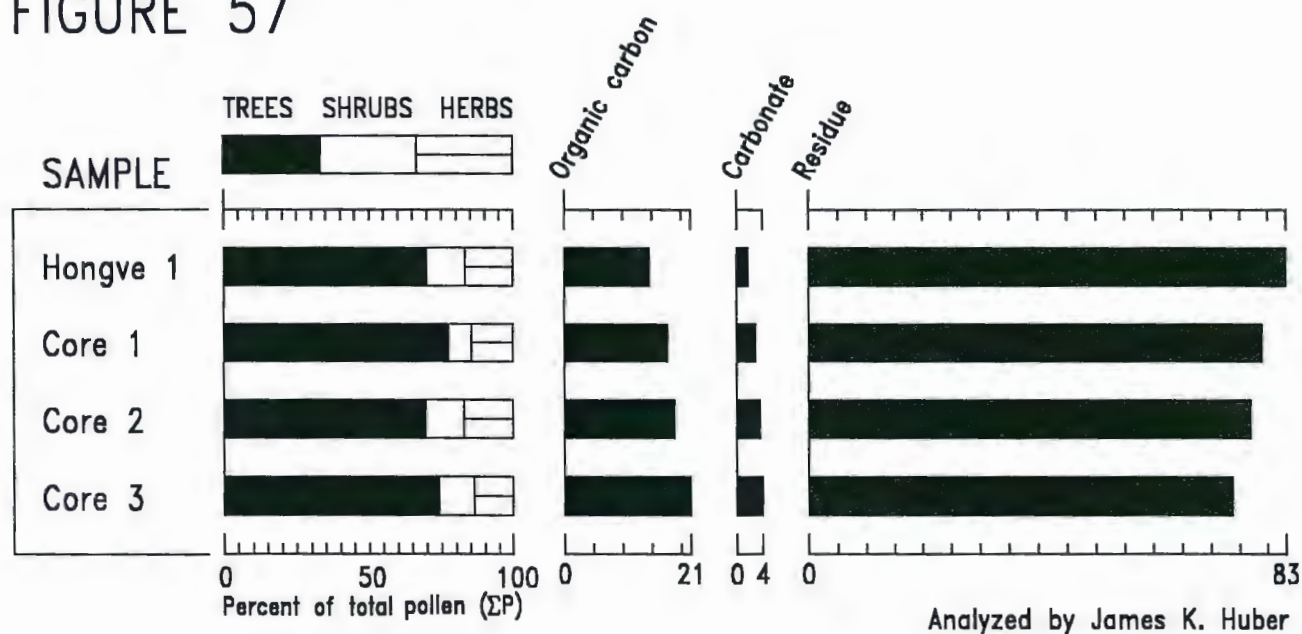
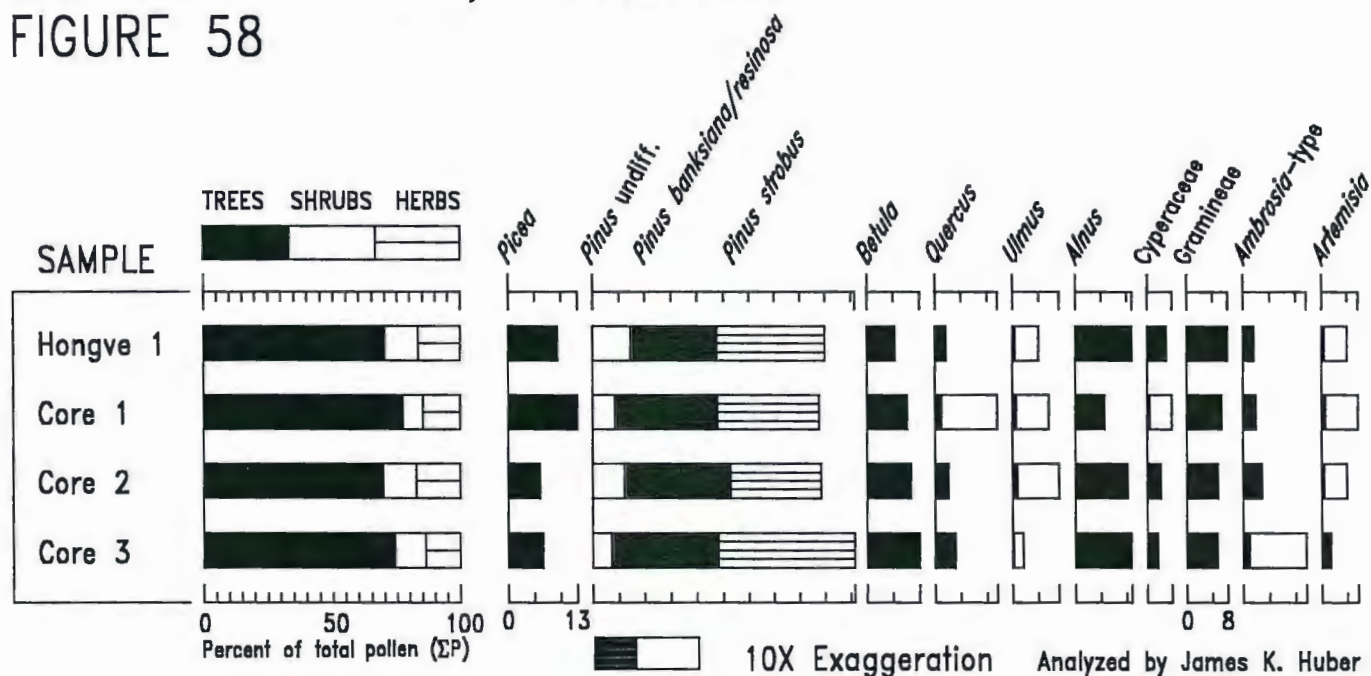


Figure 56. Map of approximate sample locations at Shannon Lake.

LOSS-ON-IGNITION PERCENTAGE DIAGRAM
SHANNON LAKE SURFACE SAMPLES
ST. LOUIS COUNTY, MINNESOTA
FIGURE 57



POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
SHANNON LAKE SURFACE SAMPLES
ST. LOUIS COUNTY, MINNESOTA
FIGURE 58



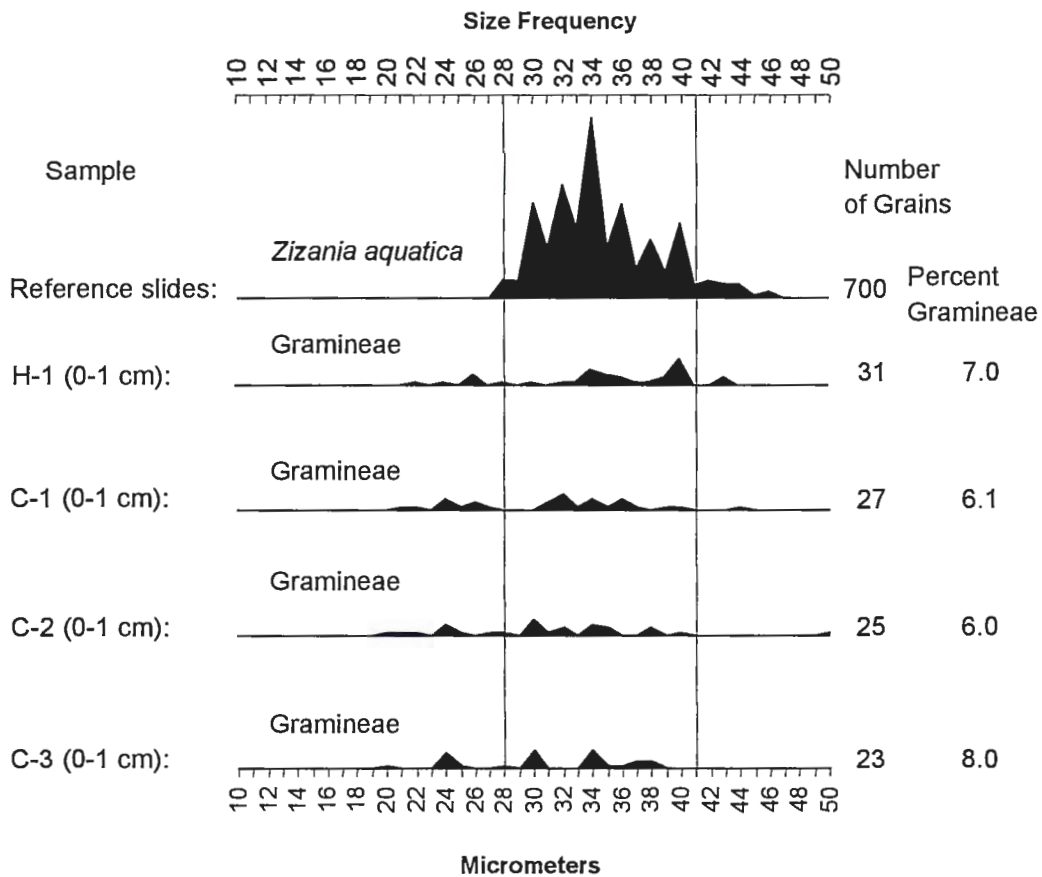


Figure 59. Comparison of *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from Shannon Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

VARIOUS WILD RICE LAKES: SURFACE SAMPLES

One or two surface samples are available for each of the following lakes:

Elbow Lake, Little Rice Lake, Moose Lake, and Northern Light Lake. For ease of discussion, these lakes are grouped together. Location data for the surface samples of these four lakes are shown in Table 11.

TABLE 11. VARIOUS WILD RICE LAKES SURFACE SAMPLE LOCATION DATA.						
Lake	Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
Elbow	C-1	701830	5304733	Wildco	1.95	29 June 1988
Little Rice	H-1	542118	5283901	Hongve	1.02	13 October 1988
Little Rice	C-1	542068	5284280	Livingstone	1.37	9 March 1989
Moose	H-1	515676	5325353	Hongve	2.38	6 October 1988
Northern Light	C-1	705821	5309404	Wildco	1.51	28 June 1988

Elbow lake is considered a poor lake for wild ricing by the 1854 Authority (2000). Wild rice only occurs in small thin stands in a few bays and shallow areas. One surface sediment sample is available from Elbow Lake (Fig. 60). Elbow Lake is located in sections 10, 11, 14, 15, T62N, R1E of the Grand Marais 7.5' quadrangle.

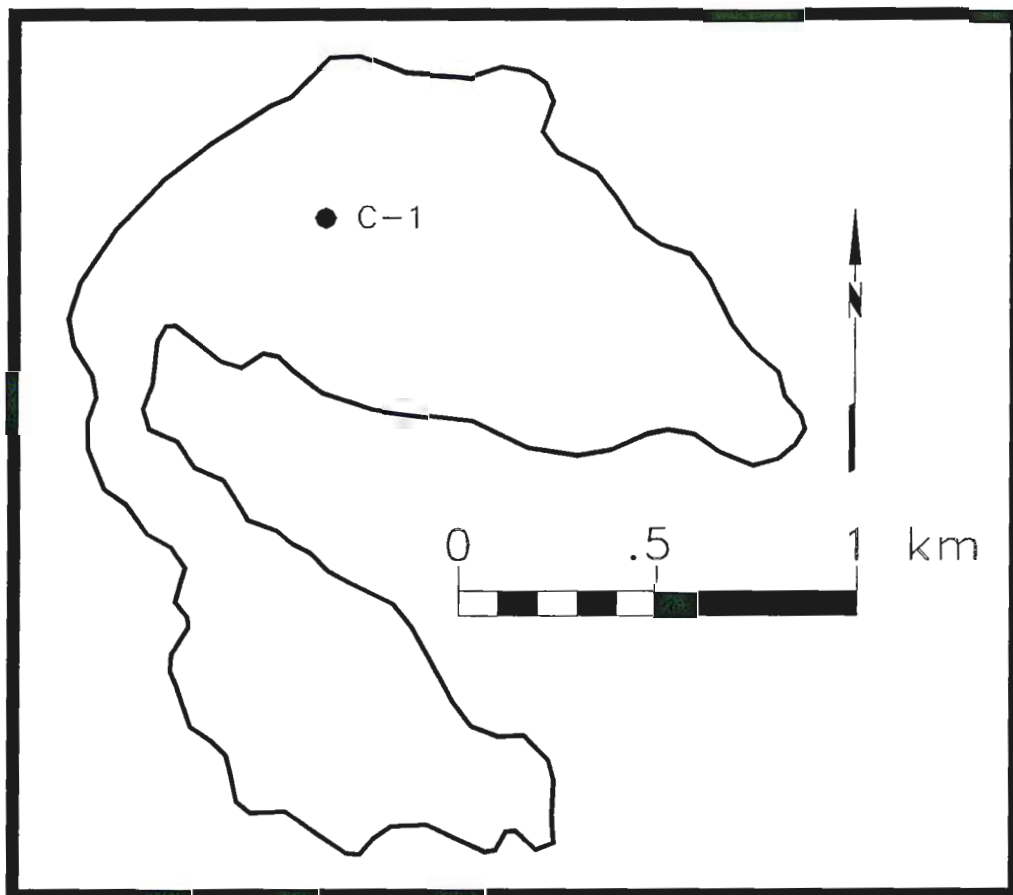


Figure 60. Map of approximate sample location at Elbow Lake.

Little Rice Lake is rated as a fair lake for wild ricing by the 1854 Authority (2000). However, I have observed a very dense stand of wild rice covering the entire lake in the past. Little Rice Lake is in section 31, T61N, R16W, section 36, T61N, R17W, section 6, T60N, R16W, and section 1, T60N, R17W of the Biwabik NW 7.5' quadrangle. Two samples are available from Little Rice Lake (Fig. 61).

Moose Lake has relatively thin stands of wild rice growing over approximately 50% of its surface. It is considered to be a fair wild ricing lake by local wild ricers (Bill Kaukonen, personal communication, 2000). One surface sediment sample was collected from an area supporting wild rice (Fig. 62). Moose lake is located in sections 27, 28, 29, 32, 33, T65N, R19W of the Orr 7.5' quadrangle.

The 1854 Authority (2000) considers Northern Light Lake as a fair wild ricing lake. One surface sediment sample is available from this lake (Fig. 63). Northern Light Lake is located in section 25, T63N, R1E and section 30, T63N, R2E of the Pine Mountain 7.5' quadrangle and sections 29, 30, 31, 32, T63N, R2E of the Northern Light Lake 7.5' quadrangle.

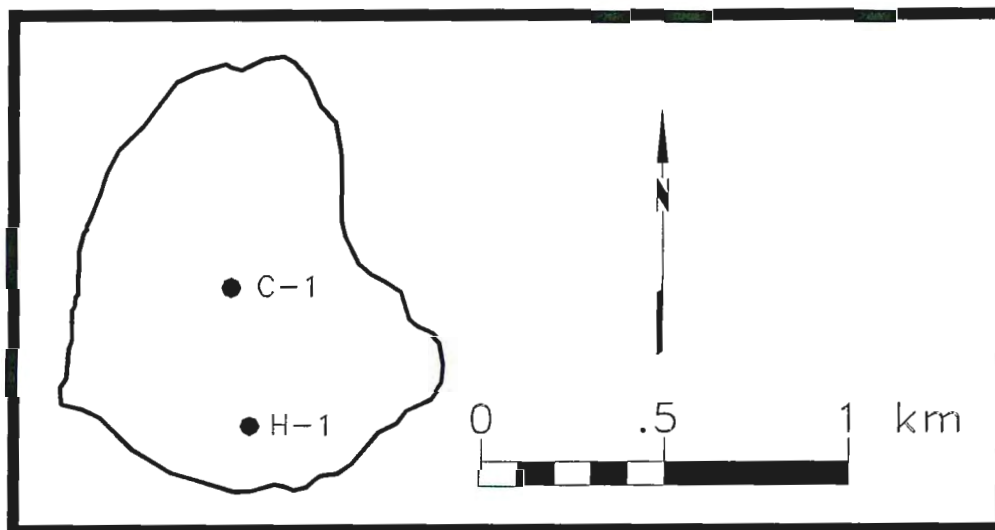


Figure 61. Map of approximate sample locations at Little Rice Lake.

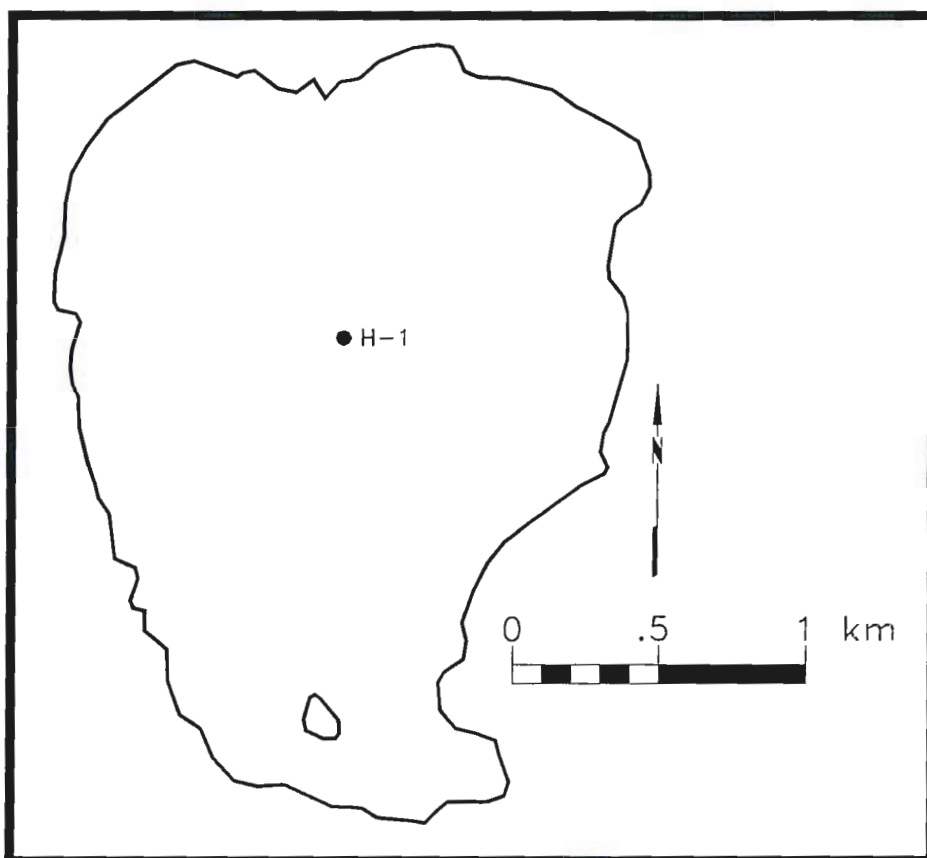


Figure 62. Map of approximate sample location at Moose Lake.

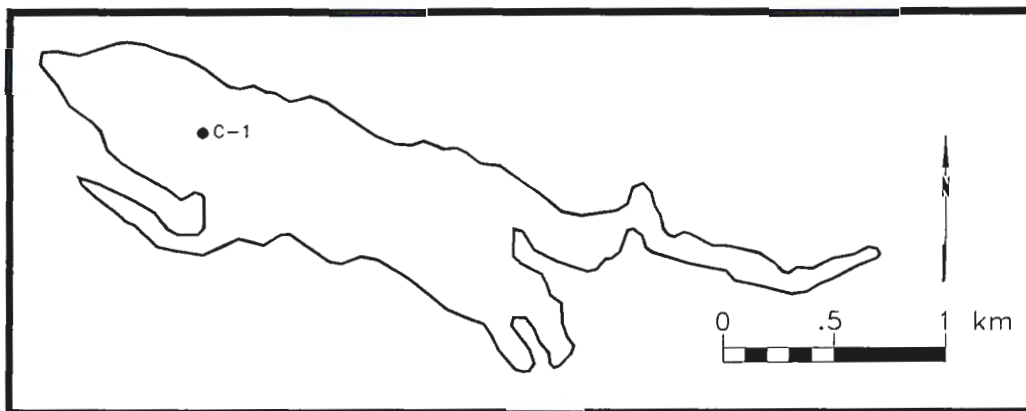


Figure 63. Map of approximate sample location at Northern Light Lake.

Loss-On-Ignition of Organic Carbon and Carbonate

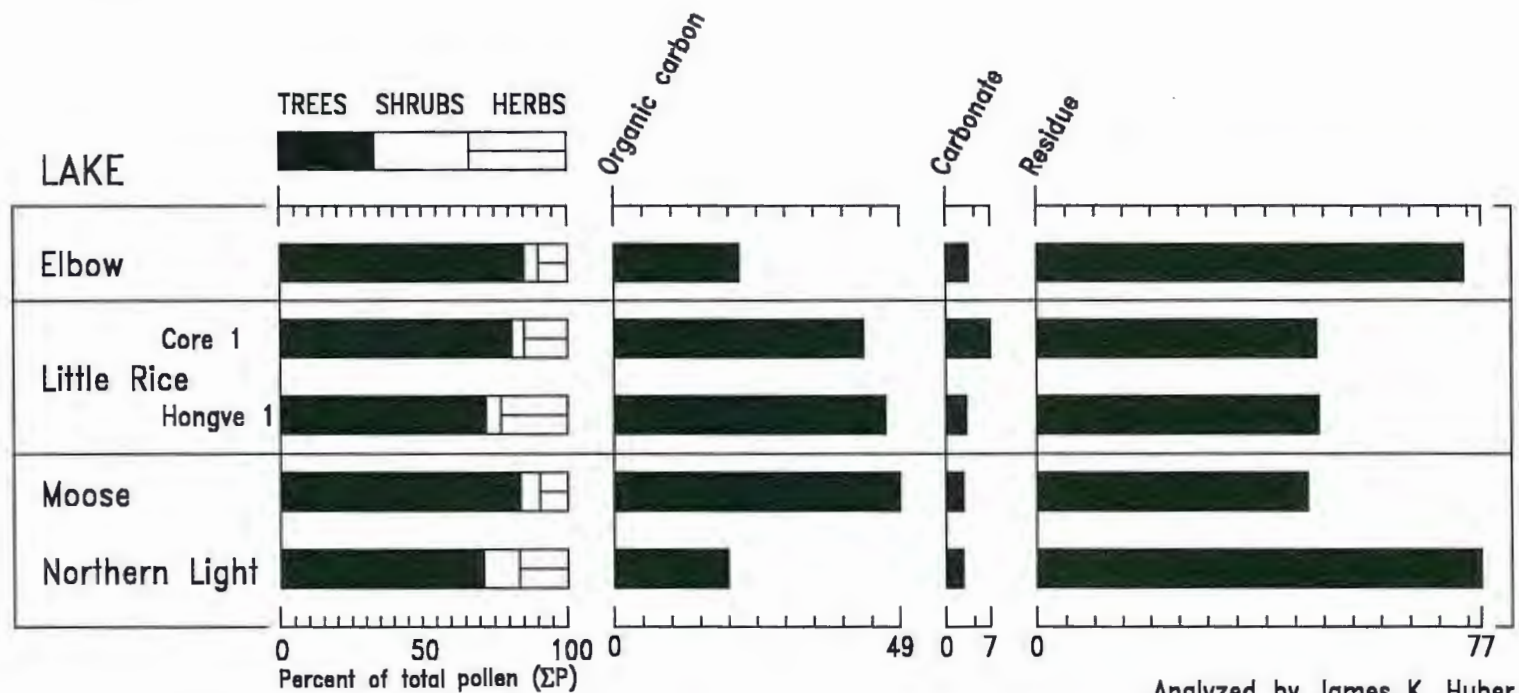
Organic carbon content is 22% and carbonate content is 4% in the Elbow Lake sediment sample (Fig. 64). At Little Rice Lake, organic carbon values range from 43% to 47% and carbonate values range from 4% to 7% (Fig. 64). Organic carbon content of the sediment is 49% and carbonate content is 3% in the Moose Lake sample (Fig. 64). The Northern Light Lake sediment sample yielded a 20% organic carbon value and 3% carbonate value (Fig. 64).

Pollen Spectra

Arboreal pollen dominates the pollen spectra at the various lakes and consists mostly of *Picea*, *Pinus*, *Betula*, and *Alnus*. Gramineae values for the various lakes range from 1.8% to 15.4% (Fig. 65). The Gramineae pollen grain size distributions and grass pollen percentages for the surface samples from Elbow, Little Rice, Moose, and Northern Light lakes are shown in Figure 66.

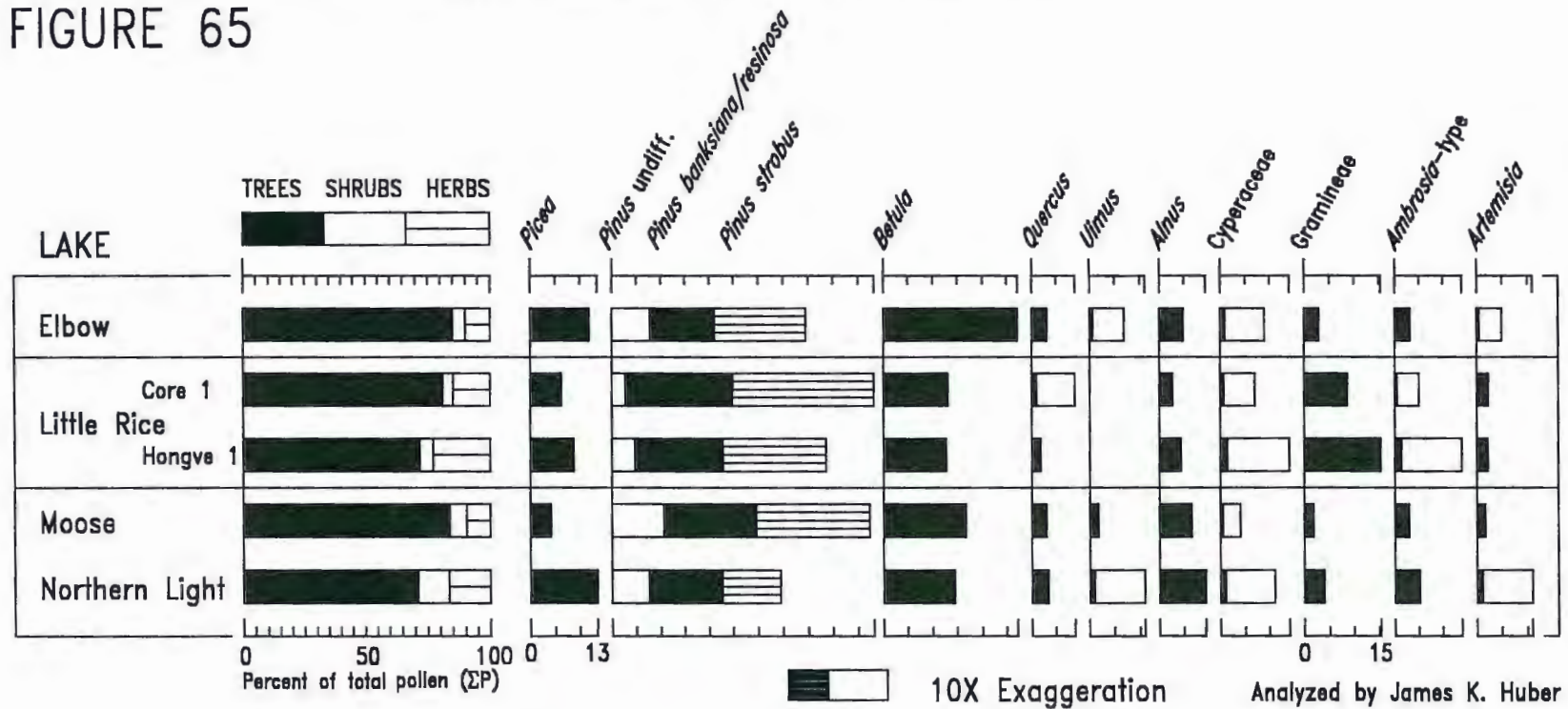
LOSS-ON-IGNITION PERCENTAGE DIAGRAM WILD RICE LAKES SURFACE SAMPLES COOK AND ST. LOUIS COUNTIES, MINNESOTA FIGURE 64

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Analyzed by James K. Huber

POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
WILD RICE LAKES SURFACE SAMPLES
COOK AND ST. LOUIS COUNTIES, MINNESOTA
FIGURE 65



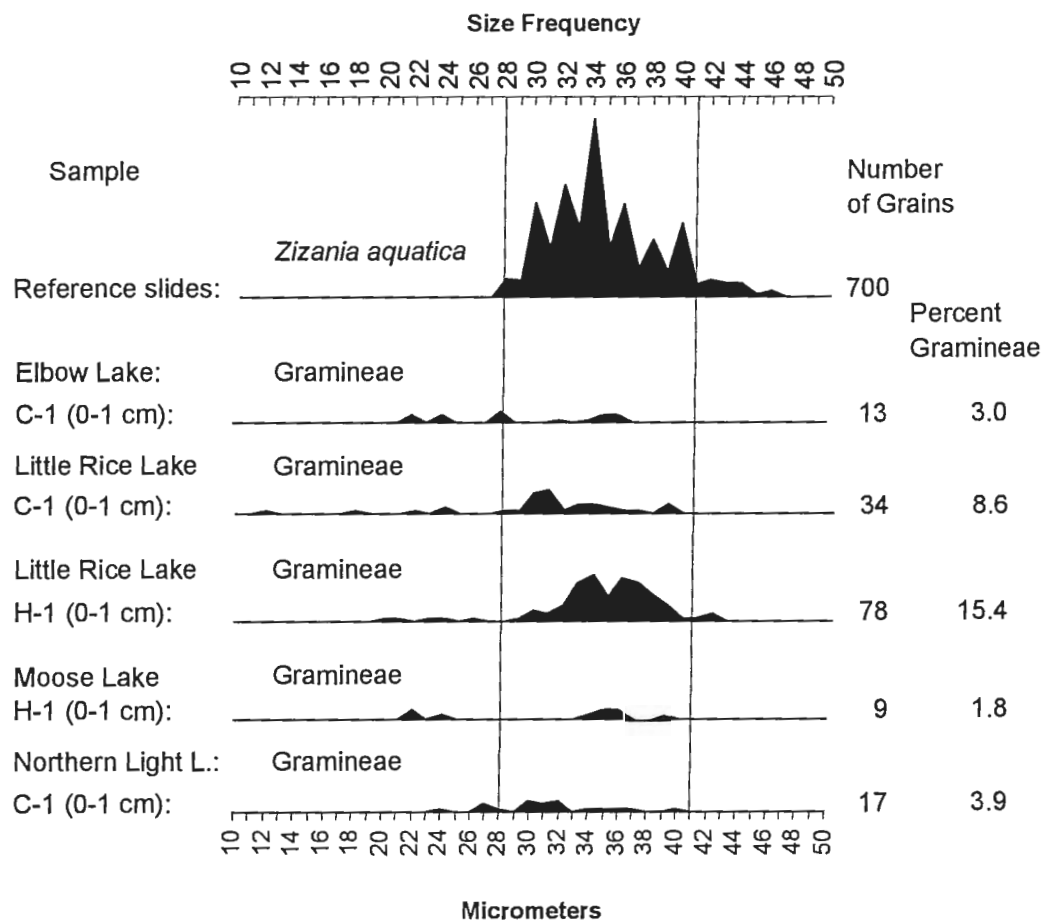


Figure 66. Comparison of *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from four lakes. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

VARIOUS NON WILD RICE LAKES: SURFACE SAMPLES

For Gramineae comparative data, one surface sample was collected from each of the following non wild rice lakes: Cloquet, Devil Track, East Bearskin, Greenwood, Musquash, and Swamper. For ease of discussion, these lakes are grouped together. Location data for the surface samples of these four lakes are shown in Table 12.

TABLE 12. VARIOUS NON WILD RICE LAKES SURFACE SAMPLE LOCATION DATA.						
Lake	Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
Cloquet	C-1	613947	5254565	Livingstone	1.58	6 July 1988
Devil Track	C-1	691392	5299686	Wildco	15.51	29 June 1988
East Bearskin	C-1	694176	5323265	Livingstone	5.48	4 March 1992
Greenwood	C-1	710298	5319519	Wildco	17.28	28 June 1988
Musquash	C-1	698576	5310062	Wildco	6.30	28 June 1988
Swamper	C-1	695808	5320715	Wildco	2.44	4 March 1992

The specific location of Cloquet Lake is given in "Cloquet Lake: Long Core." The coring site at Cloquet lake is shown in Figure 67.

Devil Track Lake is located in sections 30, 31, T62N, R1E of the Grand Marais 7.5' quadrangle and section 30, T62N, R1E, and sections 25, 26, 27, 28, 29, 34, 35 T62N, R1W of the Devil Track Lake 7.5' quadrangle. The Devil Track Lake coring site is shown in Figure 68.

The specific location of East Bearskin Lake is given in "East Bearskin Lake: Long Core." The coring site at East Bearskin Lake is shown in Figure 69.

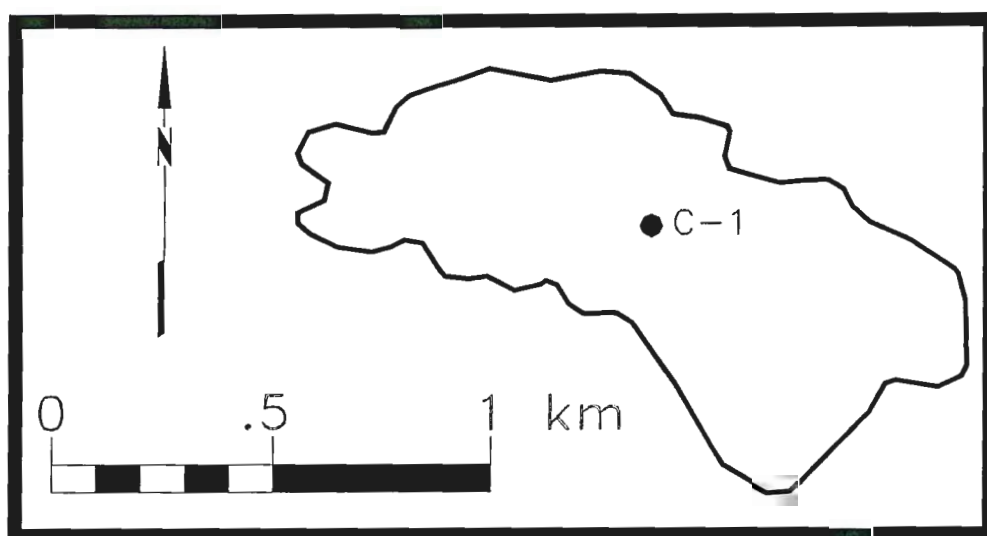


Figure 67. Map of approximate sample location at Cloquet Lake.

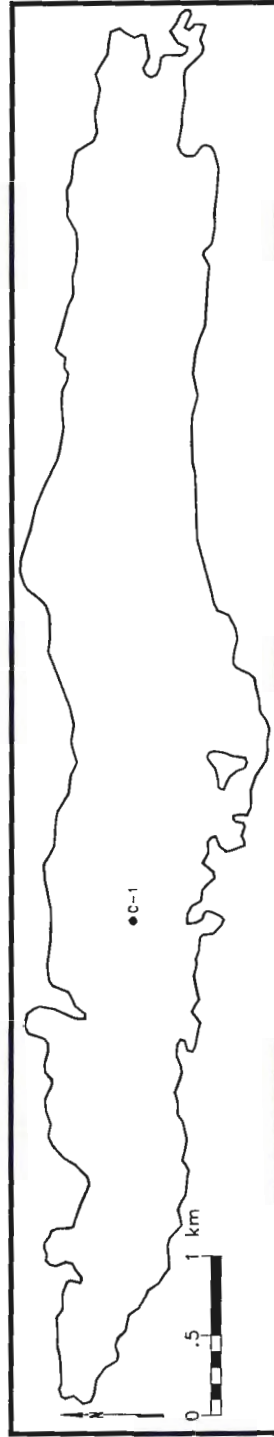


Figure 68. Map of approximate sample location at Devil Track Lake.

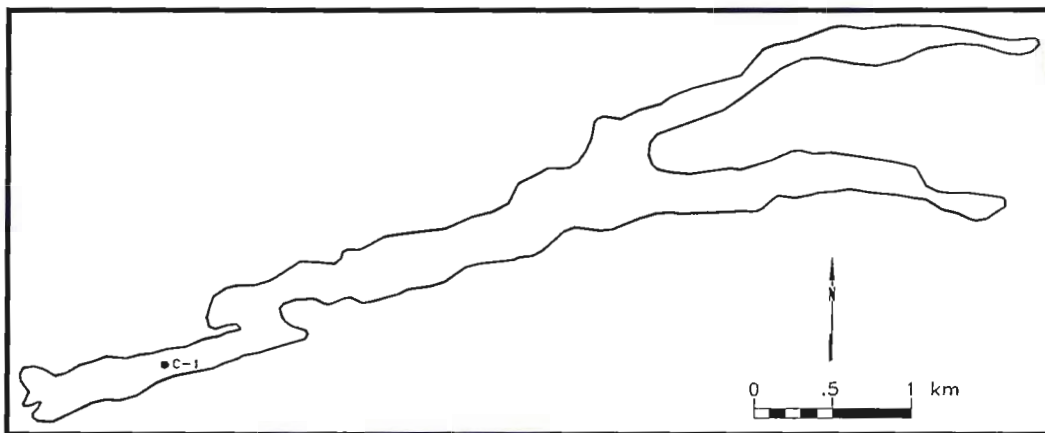


Figure 69. Map of approximate sample location at East Bearskin Lake.

Greenwood Lake is sections 26, 27, 28, 34, T64N, R2E of the Northern Light Lake 7.5' quadrangle and sections 21, 22, 23, 24 25, 26, 27, 28, T64N, R2E of the Pine Lake West 7.5' quadrangle. The Greenwood Lake coring site is shown in Figure 70.

Musquash Lake is located in sections 20, 28, 29, T63N, R1E of the Pine Mountain 7.5' quadrangle. The coring site location at Greenwood Lake is shown in Figure 71.

Swamper Lake is located in section 19, T64N, R1E of the Crocodile Lake 7.5' quadrangle and section 19, T64N, R1E of the Hungry Jack 7.5' quadrangle. The Swamper Lake coring site is shown in Figure 72.

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon content is 34% and carbonate content is 5% in the Cloquet Lake sediment sample. At Devil Track Lake, organic carbon is 22% and carbonate is 5%. Organic carbon content of the sediment is 32% and carbonate content is 5.5% in the East Bearskin Lake sample. The Greenwood Lake sediment sample yielded a 25% organic carbon value and 4% carbonate value. At Musquash Lake the organic content of the sediment sample is 37% and carbonate is 4.5%. In the Swamper lake sample, organic carbon content is 25% and carbonate content is 5.5% (Fig. 73).

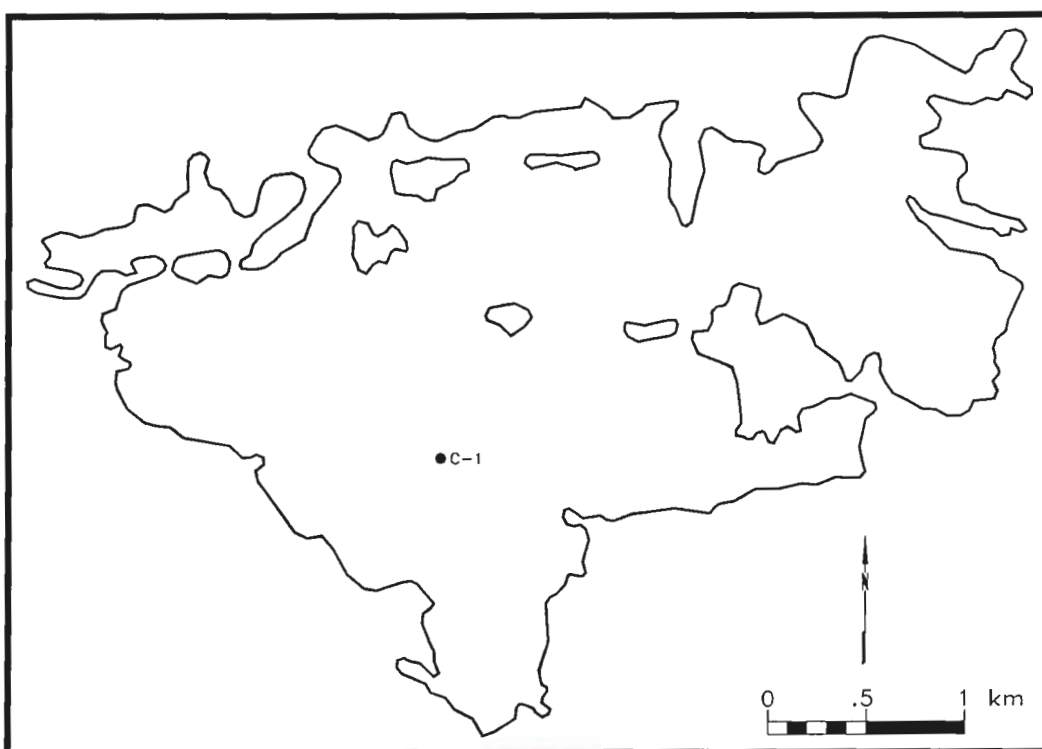


Figure 70. Map of approximate sample location at Greenwood Lake.

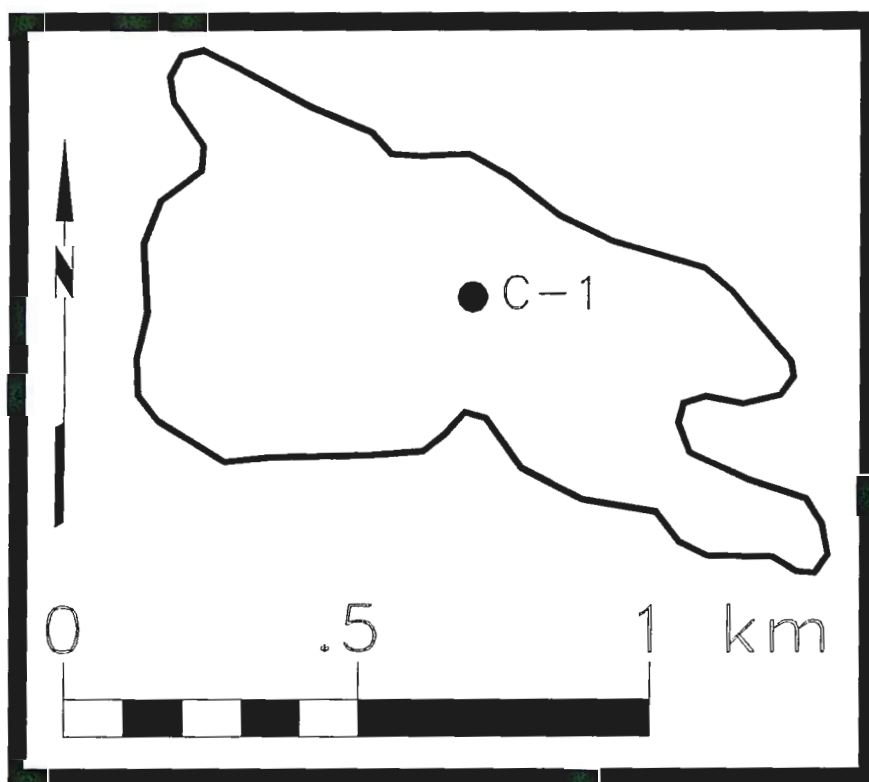


Figure 71. Map of approximate sample location at Musquash Lake.

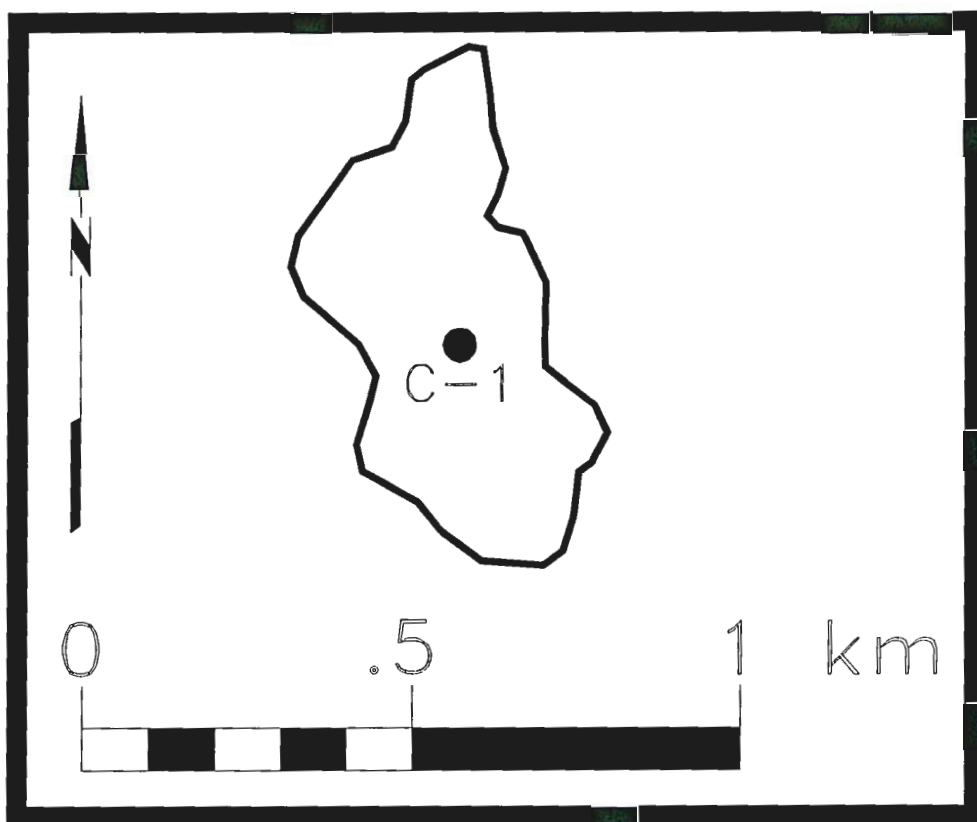
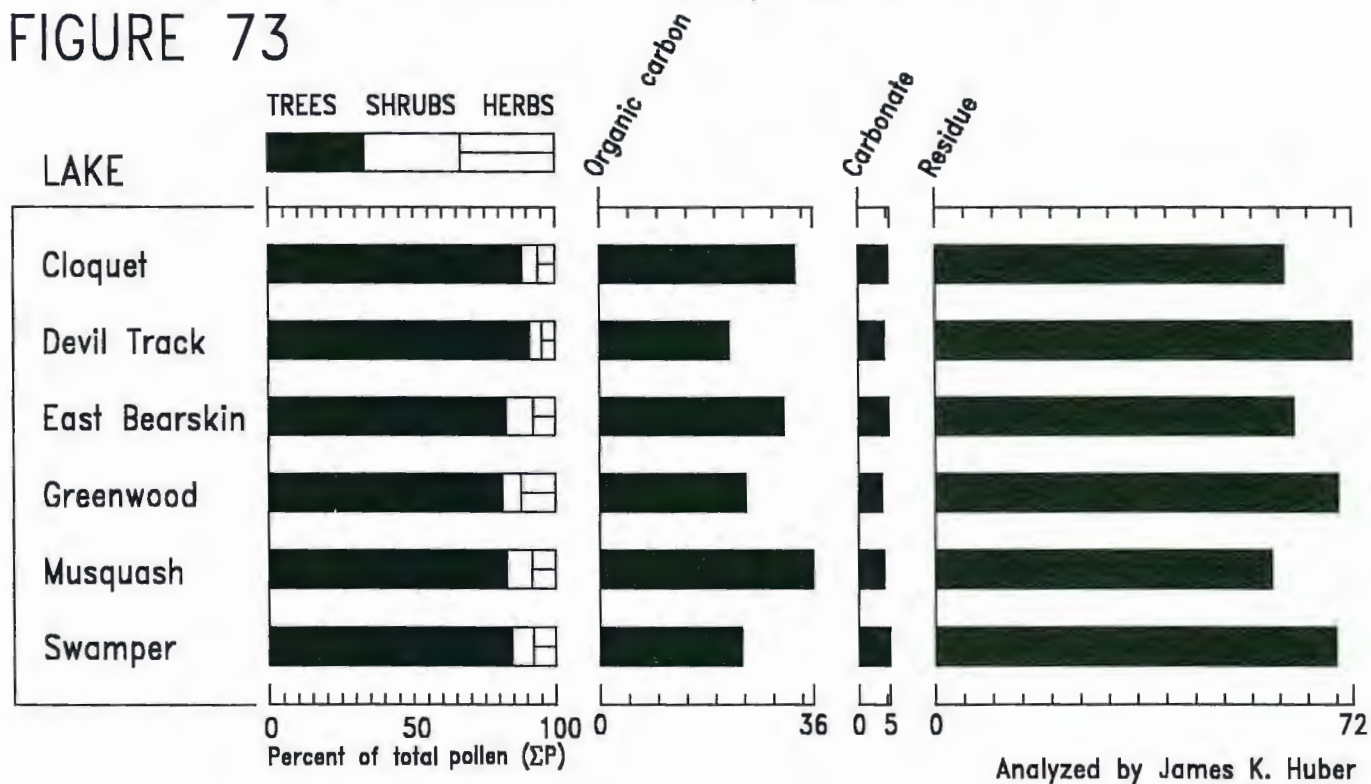


Figure 72. Map of approximate sample location at Swamper Lake.

LOSS-ON-IGNITION PERCENTAGE DIAGRAM NON WILD RICE LAKES SURFACE SAMPLES COOK AND LAKE COUNTIES, MINNESOTA FIGURE 73

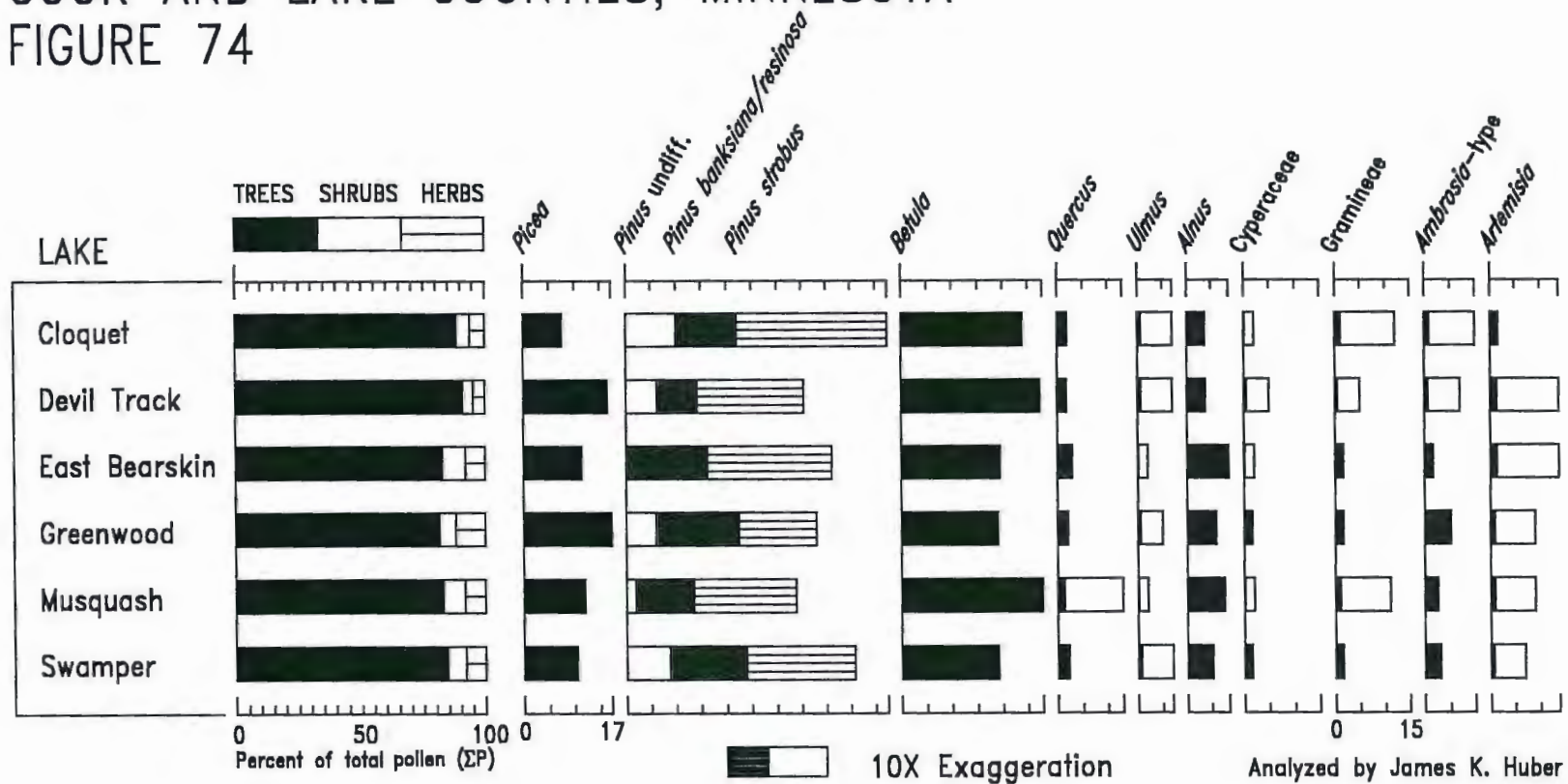


Pollen Spectra

Arboreal pollen dominates the pollen spectra of the various non wild rice lakes and consists mostly of *Picea*, *Pinus*, *Betula*, and *Alnus*. Gramineae values are less than 2% for all the non wild rice lakes (Fig. 74). The Gramineae pollen grain size distributions and grass pollen percentages for the surface samples from Cloquet Lake, Devil Track Lake, East Bearskin Lake, Greenwood Lake, Musquash Lake and Swamper Lake are shown in Figure 75.

POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA NON WILD RICE LAKES SURFACE SAMPLES COOK AND LAKE COUNTIES, MINNESOTA FIGURE 74

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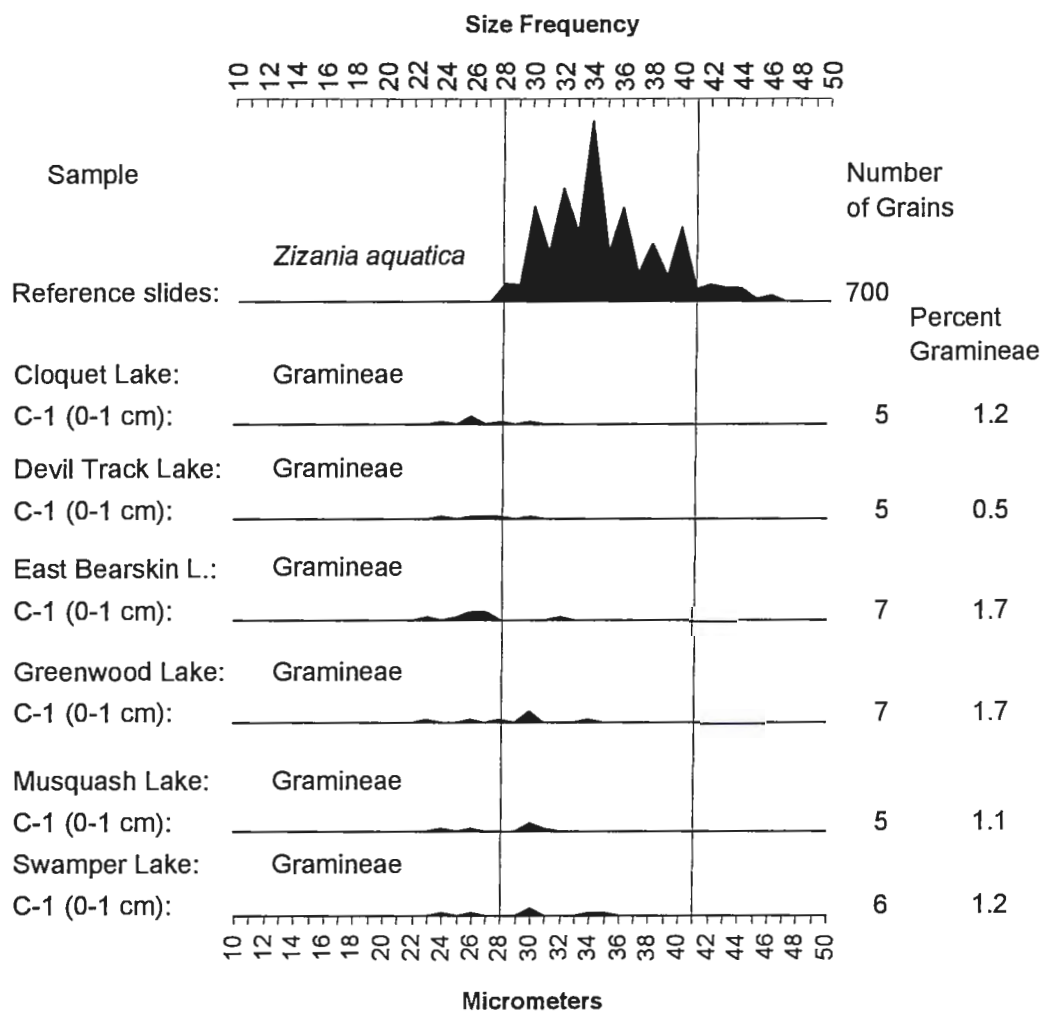


Figure 75. Comparison of *Zizania aquatica* (wild rice) with Gramineae pollen grain size distributions of surface samples from six non wild rice lakes. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

VI. DATA ANALYSIS AND INTERPRETATION

COMPARISON AND INTERPRETATION OF THE POLLEN SEQUENCES

The vegetational history of the region can be inferred from the pollen stratigraphy recorded in the four long cores (Big Rice, Cloquet, Gegoka, and East Bearskin lakes) and the results of other vegetational studies in the area. The Compositae-Cyperaceae Assemblage Zone is the oldest known to occur in northeast Minnesota (Cushing, 1967). The Compositae-Cyperaceae Assemblage Zone, which is present at Big Rice, Cloquet, and East Bearskin lakes (Fig. 76), represents a subarctic tundra of treeless or nearly treeless open vegetation of herbs and shrubs, with occasional stands of spruce or outliers of individual spruce trees. The work by Ashworth, Schwert, Watts, and Wright (1981) at the Norwood Site, Sibley County, south-central Minnesota, on insect fauna found in conjunction with the Compositae-Cyperaceae Assemblage Zone indicate an open boreal climate associated with tundra-like flora. However, this site is located much further south and may not apply to northeast Minnesota. On the other hand, Birks (1981) suggests that the term "tundra" is misleading and that there is little geologic evidence to indicate an arctic climate in Minnesota. Many of the arctic species recovered from macrofossils can be found in treeless areas within the boreal forest, as, for example, on the north shore of Lake Superior (Birks, 1981). Birks (1981) suggests that competition, rather than climate, may control the present-day distribution of many of these species. Birks (1981) also interprets the Compositae-Cyperaceae Assemblage Zone as being an open, species-rich, treeless vegetation.

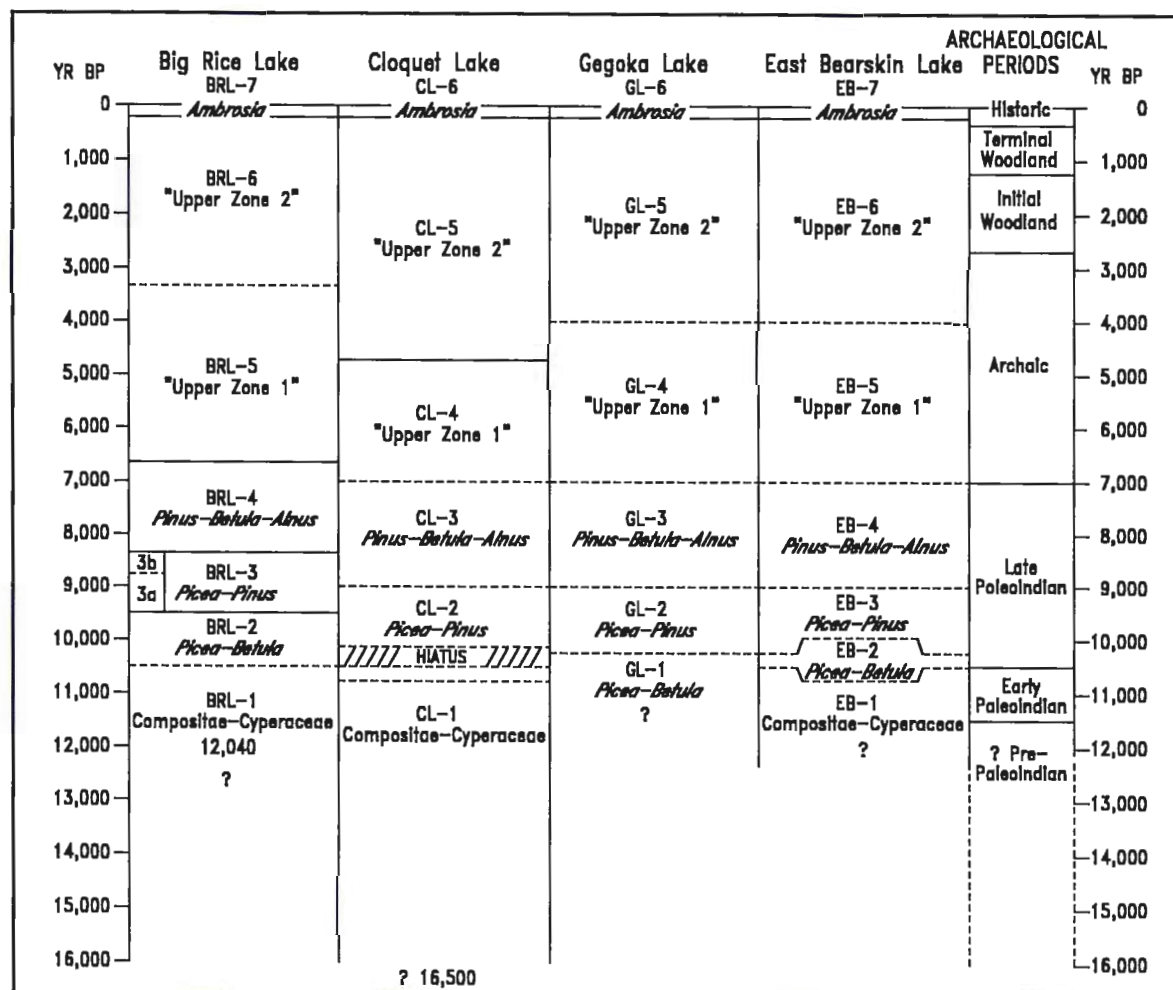


Figure 76. Comparison of four pollen sequences with archaeological periods in northeast Minnesota. Boundaries shown by solid lines are based on C-14 dates; those shown by dashed lines are tentatively drawn on the basis of correlation to similar dated pollen assemblages.

The Compositae-Cyperaceae Assemblage Zone may date to as old as 16,500 yr B.P. at Cloquet Lake, but such an old date should be regarded with caution. Wright and Watts (1969) question the validity of the 16,150 yr B.P. basal date on the Compositae-Cyperaceae Assemblage Zone at Kotiranta Lake. However, Birks (1981) finds no reasons to doubt the validity of a basal date of $15,850 \pm 240$ yr B.P. for the Compositae-Cyperaceae Assemblage Zone at Kylen Lake, which is approximately 25 km to the southwest of Cloquet Lake. Two other dates from the same stratigraphic location in other cores from Kylen Lake are $16,500 \pm 1500$ yr B.P. (Banerjee, Lund, and Levi, 1979) and $16,050 \pm 230$ yr B.P. (Lund, unpublished data in Birks, 1981), which indicates that the Cloquet Lake basal date may indeed be valid. The Compositae-Cyperaceae Assemblage Zone is missing from the base of the Gegoka Lake sequence. The well-established algae community in the basal sediments of the Gegoka Lake sequence indicates that Gegoka Lake existed prior to the base of the sediments recovered in the core rather than the absence of this zone in the vicinity.

Overlying the Compositae-Cyperaceae Assemblage Zone is the *Betula-Picea* Assemblage Zone (Cushing, 1967). The *Betula-Picea* Assemblage Zone is indicative of a shrub parkland or forest-tundra of dwarf birch and willow with scattered black and white spruce and tamarack. Juniper was probably an important shrub at East Bearskin Lake and willow is more abundant there than at Big Rice and Gegoka lakes. At Cloquet Lake, the *Betula-Picea* Assemblage Zone is missing (Fig. 76) and there is apparently a hiatus in the depositional record. The East Bearskin Lake core contains the first recorded occurrence of this zone in Cook County. The *Betula-Picea*

Assemblage Zone is not present in sediments of equivalent age at Oliver Pond and may be a very short lived zone at Cummins Pond farther to the northeast near Thunder Bay, Ontario (Julig, 1994). The *Betula-Picea* Assemblage Zone dates from 10,500 to 10,200 yr B.P. at Weber Lake (Fries, 1962) and has a date of 9,500 yr B.P. at the top of the zone at Big Rice Lake, which indicates that this vegetational community was present in the vicinity of Big Rice Lake later than in areas to the east and northeast.

The *Picea-Pinus* Assemblage Zone (Cushing, 1967) follows the *Betula-Picea* Assemblage Zone. The lower portion of this zone is transitional between the open parkland that existed in the area and conifer to conifer-hardwood forest that prevailed as spruce and pine expanded. The conifer-hardwood forest was probably a mosaic of conifers with mixed stands of hardwoods. Oak and elm were apparently important in the vicinity of Big Rice, Cloquet, Gegoka, and East Bearskin lakes. However, fir, which is prominent at Big Rice Lake, is virtually absent at the other lakes. This zone dates from approximately 9,500-8,300 yr B.P. at Big Rice Lake, from approximately 10,200-9,000 yr B.P. at Weber Lake (Fries, 1962), and from 10,700-9,250 yr B.P. at Kylen Lake (Birks (1981).

The youngest of the regional pollen assemblage zones defined by Cushing (1967) for northeast Minnesota is the *Pinus-Betula-Alnus* Assemblage Zone (Fig. 76). A mixed conifer-hardwood forest becomes the main vegetation type in this zone. Spruce, which was so abundant earlier, declines as the climate became warmer and drier, which prevented spruce regeneration. The spruce is replaced by the more

temperate red pine (Birks, 1981). The decline in *Picea* is more abrupt at Big Rice Lake than it is at Cloquet, Gegoka, and East Bearskin lakes. This may be a result of the more westerly position of Big Rice Lake. As climate became warmer and drier, the influence of the prevailing westerly winds were probably greater at Big Rice Lake than at the sites further east as the prairie expanded to its eastern-most position. The closer proximity of Big Rice Lake to the prairie border is reflected by the higher abundance of prairie-type taxa in this zone than found at the other lakes. The expansion of the prairie peninsula is reflected by only a small maxima in prairie-type plants at Cloquet and Gegoka lakes. However, the expansion of the prairie peninsula is not evident at East Bearskin Lake.

Elm, oak, birch, and alder were probably interspersed within the pine forests, which created a mosaic forest vegetation. The greater abundance of prairie-type plants in the Big Rice Lake pollen spectra suggests that the forest may have been more open or contained more forest openings. The increase in prairie-type plants probably also indicates the lowering of lake level and the expansion of mud flat communities. It is also highly probable that the introduction of wild rice to Big Rice Lake occurred at this time.

Based on varve counts, the *Pinus-Betula-Alnus* Assemblage Zone dates from 9,200 to 8,300 yr B.P. at Lake of the Clouds (Craig, 1972). It is radiocarbon dated at 9,000 to 7,000 yr B.P. at Weber Lake (Fries, 1962). At Big Rice Lake, this zone dates from 8,300 to 6,840 yr B.P.

No formal regional pollen assemblage zones have been established for pollen assemblages occurring above the *Pinus-Betula-Alnus* Assemblage Zone. However, I have referred to the two zones that are commonly found above the *Pinus-Betula-Alnus* assemblage zone as Upper Zone 1 and Upper Zone 2 for convenience (Huber, 1992). These designations for the two biostratigraphic assemblage zones will also be used here for convenience.

The pollen spectra from Big Rice, Cloquet, Gegoka, and East Bearskin lakes indicate a continuation of the mixed conifer-hardwood forest previously established in the area with a shift from red/jack pine to white pine dominance in Upper Zone 1. Pine, birch, and alder continue to be the most prominent pollen types, but the composition of the forest is changing. At Cloquet Lake, alder and birch is less prevalent and pine is more abundant than at the other lakes. Some of the deciduous components are increasing. At Big Rice and Gegoka lakes, oak becomes more prominent than at either Cloquet Lake or East Bearskin Lake. The decrease in prairie-type plants at Big Rice Lake probably reflects an elevation and stabilization of lake level following the Hypsithermal.

Dates for the rise in white pine range from 7,200 yr B.P. at Jacobson Lake (Wright and Watts, 1969) to around 7,000 yr B.P. at Lake of the Clouds (Craig, 1972) and about 6,850 yr B.P. at Big Rice Lake. The top of Upper Zone 1 is dated to 4,800 yr B.P. at Cloquet Lake. At Big Rice Lake, the top of Upper Zone 1 has an inferred date of 3,600 yr B.P. based on sedimentation rate. The data of the top of

this zone has been estimated at 4,000 yr B.P. based on correlations with other dated sequences for the base of the increase in *Picea* (Fig. 76).

The *Pinus* pollen profile at East Bearskin Lake, unlike the *Pinus* profile from Lake of the Clouds (Craig, 1972) for this period, is dominated by *Pinus strobus*. The dominance of white pine at East Bearskin Lake indicates that the refugia for jack and red pine existing northward from Weber Lake during the prairie-period, as hypothesized by Wright (1968b), probably did not exist much further east than Lake of the Clouds.

Upper Zone 2 represents the establishment of the modern mixed conifer-hardwood forest in northeast Minnesota. Spruce migrated south in response to cooler and moister conditions. The abundance of birch, alder, and other hardwoods in the Cloquet Lake watershed indicates that the forest became more interspersed with birch and other deciduous taxa here than it did at Big Rice, Gegoka, and East Bearskin lakes. The increase in deciduous taxa at Cloquet Lake probably reflects the establishment of the predominantly hardwood forest in the North Shore Highlands along the north shore of Lake Superior. It is in Upper Zone 2 that the increase in Gramineae, which is attributed to an expansion of wild rice in the lake, occurs at Big Rice Lake.

Upper Zone 2 is established earlier at Cloquet Lake than at Gegoka and East Bearskin lakes (Fig. 76), which is somewhat surprising since it is located further south. The increase in spruce may be a result of it being able to regenerate in close proximity to Lake Superior during the Hypsithermal. Cloquet Lake is on the western

edge of the Highland Moraine and at the approximate limit of the cooling and warming influences of Lake Superior. The return of spruce is later at Big Rice Lake, where it appears about 3,600 yr B.P.

Often occurring above Upper Zone 2 in northeast Minnesota is the "acme," or peak zone, which is characterized by the rise of *Ambrosia*-type pollen. This zone is commonly found in the upper sediment of pollen cores in the midwest and is associated with deforestation and land clearance by Euro-American settlement (Wright, 1971), which begins about 1890 in this area (Maher, 1977). The *Ambrosia*-type pollen maximum is subtle in the percentage pollen diagrams from Big Rice, Cloquet, and Gegoka, and East Bearskin lakes, where its presence is based largely on the increase in *Ambrosia*-type pollen concentration. The short pollen sequence from the upper lake sediments of Shannon Lake is consistent with the mixed conifer-hardwood forest present in the area today, but the ragweed rise is not evident in the pollen spectra.

COMPARISON OF POLLEN SEQUENCES TO ARCHAEOLOGICAL SITES

Artifacts recovered from the Bearskin Point site indicate that it was occupied during the Early Paleoindian Period, which dates from approximately 11,500 yr B.P. to 10,500 yr B.P., based on dates for the Clovis Culture in the American Southwest (Mason, 1981). This would place the occupation of the Bearskin Point site in the Compositae-Cyperaceae Assemblage Zone. However, the specific time or times of occupation of the Bearskin Point site within this 1,000 year period is unknown. Radiocarbon dates on charcoal and a date on occluded carbon in phytoliths from the Bearskin Point site are much younger than the artifacts indicate (Mulholland and others, 1997). At this time, the absolute dating of the site is still in question.

The vegetation in the area between 11,500 yr B.P. to 10,500 yr B.P. was most likely composed of dwarf willow, shrub birch, juniper, and perhaps individual or small stands of spruce, which is indicative of a subarctic tundra (Cushing, 1967) that had a species-rich plant diversity (Birks, 1981). Birks (1981) suggests that, although the vegetation indicates an arctic environment there is no good evidence such as periglacial features, to support this interpretation. This implies that the climate may have been open boreal like. An open boreal environment is also indicated by insects found in conjunction with this type of vegetation (Ashworth and others, 1981).

Between 11,500 yr B.P. to 10,500 yr B.P., the Bearskin Point site was located in an area bordered on the north by ice of the Rainy Lobe and the on the east by ice of the Superior Lobe. Glacial Lake Duluth was located southeast of the site and Glacial Lake Agassiz to the west (Fig. 7). This places the Bearskin Point site in

an environment similar to that of the Debert site, a large Paleoindian site in central Nova Scotia. McDonald (1968, p. 15) interpreted the paleogeography at the time of occupation as "a periglacial environment, with active ice caps as close as 60 miles to the site, extensive snow fields less than 10 miles away in the Cobequid Mountains, and a mean annual temperature below 0° Centigrade." Although McDonald (1968) has no direct evidence for it, he suggests that the Debert site was most likely occupied for the purpose of hunting Barren Ground caribou and, possibly, musk-ox and deer. Mason (1981) also suggests that Early Paleoindians were hunting caribou in the Great Lakes region. The somewhat restricted access of the area may have been ideal for hunting migrating herds of caribou.

Several *Chenopodium* (goosefoot) seeds have been recovered from the Bearskin Point site (Mulholland, 1995). Although pollen of *Chenopodium* is not diagnostic to the genus (or even family) level, Chenopodiaceae/Amaranthaceae pollen is present at this time in the pollen record (Plate 8). Yarnell (1970) reports the use of *Chenopodium* as a plant food by the Ojibway and lists several archaeological sites from which it has been recovered. *Chenopodium* seeds were recovered from the Woodland component of the Big Rice Site (Valppu, 1989). The seeds of *Chenopodium* are available in the late fall and early winter (Yarnell, 1970).

The Misiano, Cloquet Boat Landing, and Big Rice sites all have Late Paleoindian occupations, although no absolute dates are available for any of these sites. Therefore, the occupation of the sites can only be restricted to between 10,500 and 7,000 yr B.P. This means that they could be associated with any one of three

regional pollen assemblage zones. These are the *Picea-Betula* Assemblage Zone, the *Picea-Pinus* Assemblage Zone, and the *Pinus-Betula-Alnus* Assemblage Zone.

In the early part of the Late Paleoindian period, the pollen data indicate that a shrub parkland or forest-tundra prevailed at the Big Rice and Misiano sites. The vegetation was mainly composed of dwarf birch, shrub willow, and juniper, with scattered black and white spruce and tamarack. Tamarack and juniper were probably more prominent in the vicinity of Gegoka Lake (Plate 6) than at Big Rice Lake (Plate 2), with willow being more abundant at Big Rice Lake. The difference in the abundances of these taxa in the pollen diagrams indicates that vegetation was not one continuous community but rather a mosaic of communities that presented different resources for the inhabitants of the area.

At Cloquet Lake, the *Betula-Picea* Assemblage Zone is missing (Fig. 77; Plate 4) and there is apparently a hiatus in the depositional record. The *Betula-Picea* Assemblage Zone does occur approximately 15 km to the west at Weber Lake (Fries, 1962). It is postulated that the Cloquet Lake either dried up or was an ice core depression basin lake whose initial sediments were deposited on ice. As the ice melted, the initial lake basin drained, and the ice block underlying the basin melted. A second basin then formed, which is the current Cloquet Lake basin (See the Cloquet Lake section for more detail). For whatever reason, Cloquet Lake apparently did not exist between 10,500 and 10,200 yr B.P. It existed somewhat prior to and after this time. The absence of the *Betula-Picea* Assemblage Zone and, apparently, Cloquet Lake implies that the Cloquet Lake Boat Landing site was probably not

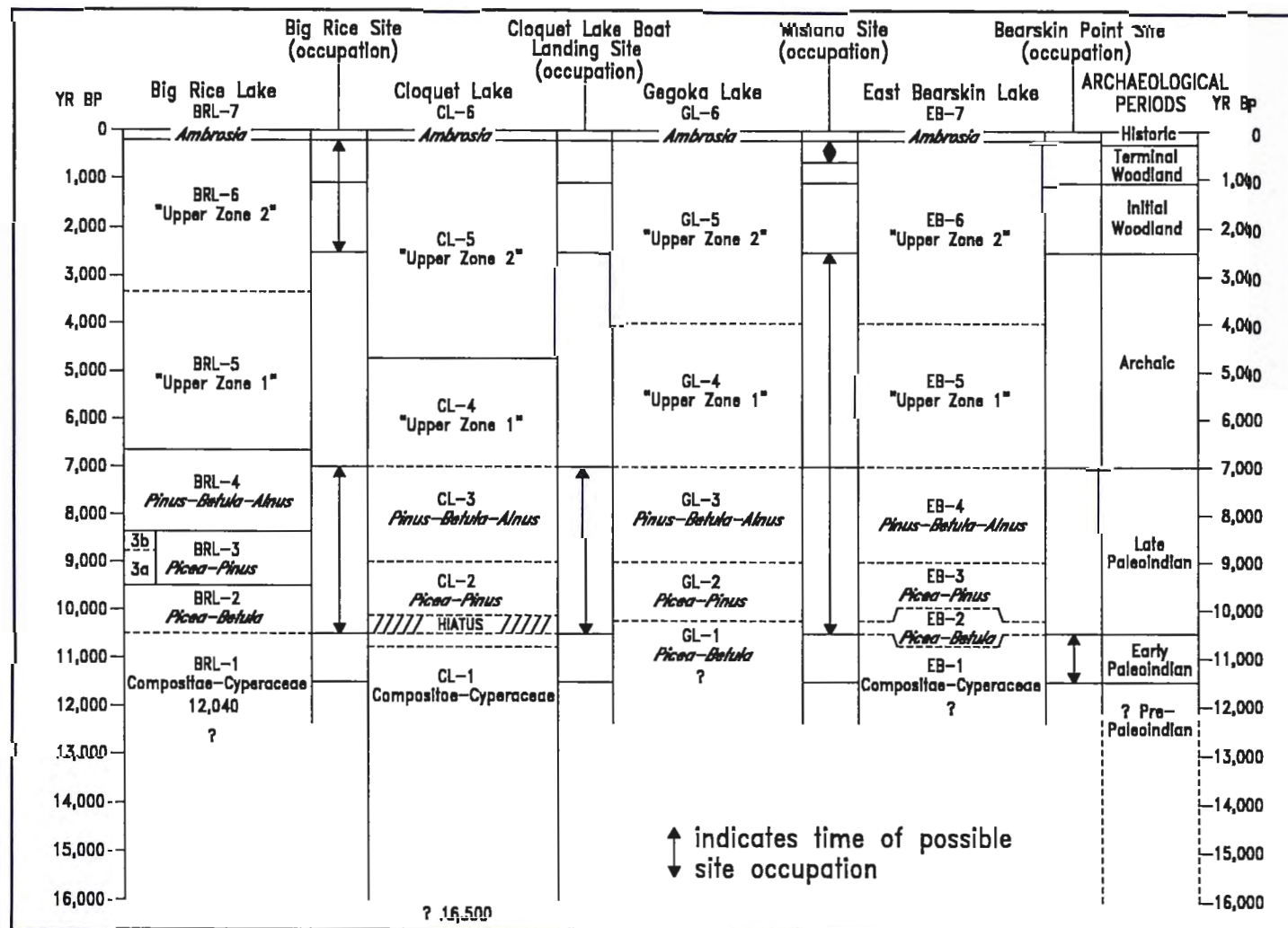


Figure 77. Comparison of pollen sequences with archaeological site occupations for four sites in northeast Minnesota. Boundaries shown by solid lines are based on C-14 dates; those shown by dashed lines are tentatively drawn on the basis of correlation to similar dated pollen assemblages.

occupied at this time or that occupation of the site was not dependant on the lake as a water source or for water related activities.

By approximately 10,200 yr B.P. at Gegoka Lake (Fig. 77), the vegetation was changing from a shrub parkland or forest-tundra to a conifer-hardwood forest (*Picea-Pinus* Assemblage Zone). This forest was a mosaic of conifers with mixed stands of hardwoods that were dominated first by spruce and then by pine. Oak, elm, and ash probably occurred locally in groves. The presence of oak would expand the potential subsistence base, although there is no evidence of the use of acorns by Paleoindians. The basal portion of this zone is apparently missing at Cloquet Lake, but the presence of the conifer-hardwood forest is indicated in the sediment immediately above the hiatus (Plate 4). The transition from the forest-tundra to a conifer-hardwood forest occurred at approximately 10,200 yr B.P. at Cloquet and Gegoka lakes, but it did not occur at Big Rice Lake until approximately 700 years later (Fig. 77). This would indicate that the Late Paleoindians could move back and forth through different ecotones, as different subsistence resources became available. This type of vegetation persisted until about 9,000 yr B.P. at Gegoka and Cloquet lakes, but lasted until about 8,300 yr B.P. at Big Rice Lake.

By about 9,000 yr B.P. at Cloquet and Gegoka lakes and about 8,300 yr B.P. at Big Rice Lake (Fig. 77), the pine forests became more interspersed with elm, oak, birch, and alder which created a different mosaic of forest vegetation (*Pinus-Betula-Alnus* Assemblage Zone), both temporally and spatially. The abundance of spruce was declining as the climate became warmer and drier. Spruce continued to be more

abundant in the vicinity of the Misiano and Cloquet Lake Boat Landing sites and northern Bearskin Point site than it was at the Big Rice site. In the vicinity of the Big Rice site, the forest was more open or there were more forest openings, as indicated by the presence of prairie-type taxa in the Big Rice Lake pollen record, which broadened the habitat types available to both humans and fauna. The level of Big Rice Lake may have lowered as the climate continued to warm, which probably affected the availability of aquatic and wetland resources, such as waterfowl, mussels, fish, and aquatic and semiaquatic plants. The increase in abundance of Gramineae pollen at about 8,300 yr B.P. may indicate the first availability of wild rice to humans in the area. *Chenopodium* values also increase at Big Rice Lake during this period, which suggests that those seeds were present in sufficient quantity to serve as a food source. At Cloquet and Gegoka lakes, *Chenopodium* was probably more abundant at this time.

The Late Paleoindian Period ended in northeast Minnesota about 7,000 years ago as white pine migrated into the area. The Late Paleoindian Period lasted for approximately 3,500 years in northeast Minnesota. The Late Paleoindian Culture inhabiting northeast Minnesota had to adapt to changing environmental and climatic conditions, which probably resulted in a shift in the type of game available. Throughout the Late Paleoindian Period, the pollen data indicate that each vegetational zone through time was a mosaic of somewhat different vegetational communities. Each of these communities would have offered different available resources, although currently the fossil data are too limited to indicate just what was

actually available. However, the vegetation in the early Late Paleoindian Period was much more suited for caribou and possibly musk-ox than it was at the end of the period, when deer and moose were available.

Late Paleoindians are considered Big Game hunters. However, recent work by Kuehn (1998) indicates that the Late Paleoindians utilized a wide variety of game, including large and medium sized mammals, as well as turtle, bird, and fish (See pages 39-40). Kuehn (1998) suggests, based on data from the Sucies and Deadman Slough sites in northern Wisconsin, that Late Paleoindians and Early Archaic peoples were utilizing a generalized foraging strategy and exploiting a wide variety of habitats. Although paleobotanical remains are almost nonexistent for the Late Paleoindian, there is no reason to believe that Late Paleoindians did not also exploit a wide variety of plants.

By the end of the Late Paleoindian Period, the vegetation in northeast Minnesota was essentially the same as it was at Euro-American contact. The major difference being the relative abundance of different taxa. Mason (1981) notes that the Upper Great Lakes Native Americans alone utilized at least 373 native plants. Probably at least 500 plants were actually used because not all aboriginal plant use was recorded. A great many of these plants are probably represented in the pollen record, although not readily apparent in the pollen diagrams because of the limitations of pollen identification to species and the small amount pollen produced by some plants. A good example of the limitations of pollen data in identifying a specific food plant is the family Rosaceae. This family includes the raspberries, blackberries,

choke cherry, pin cherry, juneberry, and strawberry, to name a few. None of these plants can be identified past the level of family (Rosaceae) let alone species.

The Misiano site was occupied during the Archaic and has not been radiocarbon dated. In northeast Minnesota, the Archaic is poorly understood because of the lack of identified Archaic sites. The Archaic Period begins about 7,000 yr B.P. and lasts until the beginning of the Initial Woodland between 2,500 and 2,200 yr B.P. Because of the lack of radiocarbon dates, the time of transition from Archaic to Woodland is still speculative. The Misiano site has been interpreted as a site for the construction of dugout canoes based on the wood working artifacts recovered.

The vegetation in the area of the Misiano site is basically a continuation of the mixed conifer-hardwood forest that developed during the Late Paleoindian Period. The major vegetational change that occurs near the Misiano site is the shift from red/jack pine to white pine dominance. The migration of white pine into the area would have provided trees large enough for dugout canoes. This is also the time (7,000 yr B.P.) of maximum expansion of the prairie peninsula, when temperature and aridity increased (Zeeb and Smol, 1993). Spruce is virtually absent from the area from approximately 7,000-4,000 yr B.P., as the warmer, drier climate prevented the regeneration of spruce (Birks, 1981). Oak is more abundant, especially around Big Rice Lake. Elm and other deciduous trees increase at the expense of birch in the vicinity of the Misiano site. The increase in oak and other hardwoods indicates the probability of the availability of acorns and hazelnuts. The variation in abundance of

major taxa in the pollen diagrams indicates the probable presence of a mosaic of interspersed conifers and hardwoods.

By 4,000 yr B.P., the vegetation in the vicinity was again undergoing change as climate began to ameliorate. Spruce migrates back into the area as conditions became cooler and moister. There is an increase in cedar and tamarack as birch becomes more abundant at the expense of oak. The reduction of oak with cooler, moister conditions also reduced the amount of acorns available as a food source.

Chenopodium, another food source, is also less abundant. Near the end of the Archaic, an increase in Gramineae pollen values at about 3,600 yr B.P. at Big Rice Lake indicates an abundance of wild rice in the area. Although there is little evidence that wild rice was abundant in Gegoka Lake at this time, it may have been present adjacent to the Misiano site on the McDougal Lakes chain or in the Stony River.

The Archaic Period is coincident with the migration of white pine into the area. Whether or not these two events are related is not known. It is possible that environmental factors associated with the migration of white pine may have initiated a change in subsistence and settlement patterns. The shift to the Archaic in northeast Minnesota also occurs at a time when lake levels had lowered from climatic warming. The paucity of Archaic sites is probably the result, in part, of the Archaic peoples inhabiting shorelines that later became submerged when cooler, moister conditions returned at approximately 4,000 yr B.P. However, this does not account for the apparent lack of sites from the Late Archaic.

Mason (1981) suggests that the Ritchie-Fitting Hypothesis is another explanation for the paucity of Archaic sites in the Upper Great Lake. According to the Ritchie-Fitting model, much of the Great Lakes area was a closed coniferous forest that was poor in game and edible plants between 10,000 and 8,500 yr B.P. However, this model is not applicable to northeast Minnesota where the transition to the Archaic did not occur until 1,500 years later, at approximately 7,000 yr B.P. The Ritchie-Fitting Hypothesis is more applicable to the eastern Great Lakes where the transition from Paleoindian to Archaic occurred at approximately 9,000 yr B.P.

The Big Rice site is one of the major Woodland Tradition sites in northeast Minnesota. It was inhabited almost continuously from the Initial Woodland through the Historic Period. The Big Rice site contains Laurel, as well as Blackduck, Selkirk, and Sandy Lake ceramics (Peters and Motivans, 1984; Peters and Motivans, 1985). Based on radiocarbon dates, the site was first occupied about 2,000 yr B.P. (Valppu and Rapp, 2000). At this time, the vegetation in the vicinity of the site was little different from that encountered at the time of contact, a mixed conifer-hardwood forest with a greater abundance of spruce than occurred in the Archaic. However, based on the Gramineae abundance, wild rice had become abundant on the lake, thus providing a major food source at this time. The expansion of wild rice in Big Rice Lake is estimated to have occurred at approximately 3,600 yr B.P. This is about 1,600 years before there is evidence for its utilization at the Big Rice site.

The Misiano site was also occupied during the Terminal Woodland based on the presence of Sandy Lake pottery. The vegetation in the vicinity of the Misiano site

was characteristic of the modern mixed conifer-hardwood forest. The presence of pottery may indicate the utilization of wild rice on McDougal or Stony lakes. However, there is no evidence currently available to support this possibility.

Based on the palynological record, the Early Paleoindian inhabitants of the Bearskin Point site would have lived in species-rich subarctic tundra. The vegetation was most likely composed of dwarf willow, shrub birch, and juniper, perhaps with individual trees or small stands of spruce. During the time of possible Late Paleoindian occupation of the Misiano, Cloquet Boat Landing, and Big Rice sites, the vegetation underwent several major changes. In the early part of the Late Paleoindian period, the pollen data indicate that a shrub parkland or forest-tundra composed of dwarf birch, shrub willow, juniper, and scattered black and white spruce and tamarack prevailed. Beginning about 10,200 yr B.P., the vegetation was changing to a conifer-hardwood forest that was first dominated by spruce and then, by pine. This forest was a mosaic of conifers with mixed stands of hardwoods.

By approximately 8,300 yr B.P., the conifer-hardwood forest had become a mixed conifer-hardwood forest dominated by pine, birch, and alder interspersed with elm and oak. During the Archaic, the vegetation in the area of the Misiano site was a continuation of the mixed conifer-hardwood forest, although pine dominance had shifted from red/jack pine to white pine. During Woodland occupation of the Big Rice and Misiano sites, the vegetation was little different from that encountered at the time of contact, that is, it was a mixed conifer-hardwood forest with a greater abundance of spruce than occurred in the Archaic.

DEVELOPMENT OF CRITERIA FOR THE DETERMINATION OF THE PRESENCE OF WILD RICE IN THE PALEOECOLOGICAL RECORD

There are basically three ways to identify the likely presence of wild rice in the paleoecological record. The best and most absolute way is by the presence of wild rice macrofossils (McAndrews, 1969; Birks, 1976). The second way is by Gramineae pollen grain size distribution (McAndrews, 1969; Yourd, 1988). The third way is to compare the abundance of Gramineae in the pollen profile to control cores (McAndrews, 1969; Yourd, 1988)

McAndrews (1969) recovered wild rice seeds in conjunction with extremely high Gramineae pollen values from the upper sediments of a core from Rice Lake in Becker County, Minnesota. At Wolf Creek in Morrison County, Minnesota, Birks (1976) recovered wild rice grains from the same section of the core in which a Gramineae rise of over 40% occurs. The Gramineae rise dates between 10,000 and 9,000 yr B.P. (Birks, 1976).

Gramineae pollen grain size was used by McAndrews (1969) to determine the presence of wild rice in Rice Lake, Minnesota. By measuring 100 wild rice pollen grains from two reference slides, he determined that 96% of the wild rice pollen grains fell within the 25-32 μm range. Subsequently, McAndrews (1969) measured the size of 50 grass pollen grains for 16 levels in the pollen sequence and found that the grass grains were concentrated between 25 μm and 32 μm , with a peak at 29 μm in the pollen zones with extremely high Gramineae values (Fig. 78). Based on this data and radiocarbon dating, McAndrews (1969) estimated that wild rice spread over most of the lake about 1,935 yr B.P.

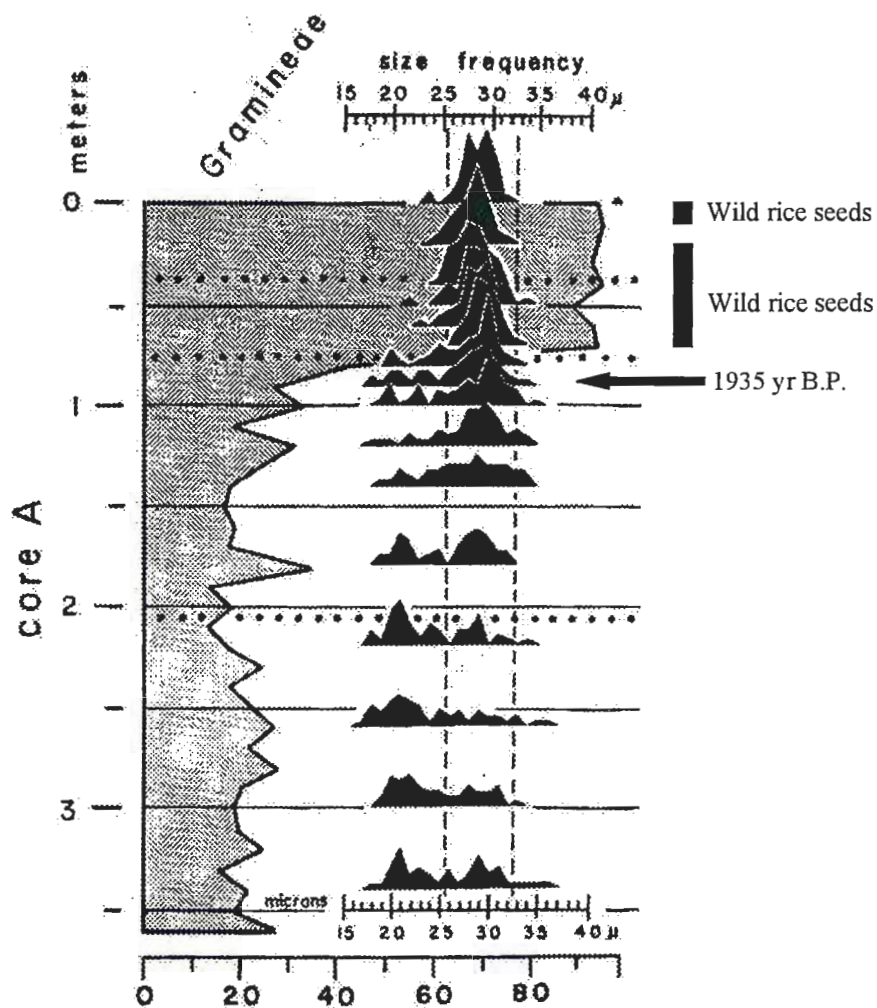


Figure 78. Comparison of grass pollen percentages and Gramineae grain size distributions with the presence of wild rice seeds, Rice Lake, Becker County, Minnesota. Modified from McAndrews, 1969.

Yourd (1988) used a combination of abundance and Gramineae grain size to determine the history of wild rice at Marquette Pond in Beltrami County, Minnesota (Fig. 79). Yourd divided the Gramineae pollen grains into two groups based on size and to some extent surface sculpturing of the Gramineae pollen grains. Gramineae pollen grains were divided into a *Zizania-Andropogon* (wild rice-bluestem) group and a non *Zizania-Andropogon* group of Gramineae grains that were less than 25 μm in diameter. The *Zizania-Andropogon* group of Gramineae used by Yourd (1988) is roughly equivalent to the *Glyceria*-type (manna-grass) Gramineae group versus the *Phragmites* (reed), *Dactylis* (orchard-grass), *Festuca* (fescue), and cereal types of Faegri and Iverson (1975). Although Yourd divided the Gramineae pollen into two groups, these two groups are not mutually exclusive because of the wide range of size and sculpturing of Gramineae pollen. Based on the results of the Gramineae pollen grain size measurements, Yourd deduced that the non *Zizania-Andropogon* group of Gramineae pollen grains correspond to those of Martin Pond (a non wild rice lake Gramineae profile) for total Gramineae pollen and that the *Zizania-Andropogon* group of Gramineae pollen grains probably represent the local influx of wild rice pollen (Fig. 79). Based on the Gramineae grain size distribution and abundance, Yourd surmised that wild rice had probably become established in Marquette Pond by 3,500 B.P. and had expanded or become dense enough to provide a Gramineae pollen influx similar to the current influx of Gramineae pollen (50-55%) by 2,000 B.P.

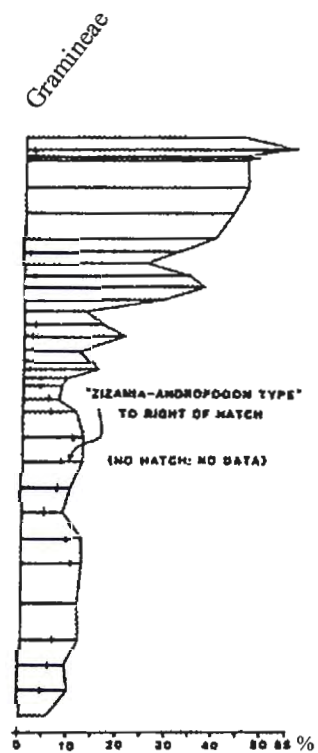


Figure 79. Gramineae pollen percentage profile from Marquette Pond, Beltrami County, Minnesota. Modified from Yourd, 1988.

In his 1988 study, Yourd initially attempted to establish the past history of wild rice in Lake Marquette based on Gramineae pollen abundance. Lake Marquette is a 160 ha basin that supports about 8 ha of wild rice, about 5% of the lake surface (Yourd, 1988). Analysis of two cores from relatively deep open water away from the wild rice beds yielded Gramineae percentages ranging from 1% to 5%, which Yourd interpreted as not indicating the local influx of Gramineae (wild rice). However, analysis of two surface sediment samples, one from within each of two different wild rice beds, yielded Gramineae pollen percentages of 30% and 47% of the total pollen sum. Yourd's data indicate that low Gramineae pollen percentages does not necessarily indicate the absence of harvestable quantities of wild rice.

Wilson and Potzger (1943) noted the high abundance of Gramineae pollen grains sediments from lakes supporting or that had supported wild rice in the Anoka Sand Plain in Anoka County, Minnesota. This led them to interpret the abundance of Gramineae pollen as a result of shallowing water and the invasion of wild rice.

Janssen (1966) has demonstrated the association of high Gramineae pollen values from surface sediments associated with or very close to wild rice stands at Floating Bogs I and II at Lake Itasca in Clearwater County, Minnesota. In this study, Janssen excluded Gramineae pollen from the main pollen sum calculating the Gramineae percentages based on the main pollen sum plus Gramineae pollen. Therefore, his Gramineae percentages sometimes exceed 100%. Based on this method of determining Gramineae percentages, Janssen (1966) recorded Gramineae percentages ranging from 20% to 200% from surface samples associated with wild

rice stands. Janssen (1966) also recorded Gramineae values of up to 300% in a grass/sedge uplands near St. Cloud, Minnesota, using this same method.

Yourd (1988) suggests that a 40% Gramineae pollen value indicates the presence of wild rice in harvestable quantities. He determined this value based on the following deductions: 1) typically Gramineae values for the mid Holocene in Minnesota range from <5% to 15% and late Holocene values do not exceed 5%; 2) Gramineae values between 25% and 30% are high for most coring sites in Minnesota; 3) Gramineae values exceeding 35% to 40% are almost certainly a result of local influx. Based on these criteria, Yourd (1988) subsequently looked at Gramineae pollen profiles from 15 published and unpublished sites in Minnesota and deduced that wild rice was probably present in Minnesota throughout the Holocene but may not have become extensively available until the late Holocene.

As mentioned earlier, wild rice has a monoporate (single pore) pollen grain (Fig. 18) that is similar in size and surface sculpturing to most other grass pollen and cannot be identified to species with absolute certainty. McAndrews (1969), in the above mentioned study, determined that 96 of 100 wild rice reference grains fell within 25 μm and 32 μm . The published size of *Zizania aquatica* (wild rice) in the pollen key "Key to the Quaternary pollen and spores of the Great Lakes Region" by McAndrews, Berde, and Norris (1973) has a size range of 32 μm to 36 μm and an average of 34.2 μm . The size range and average for wild rice pollen grains is based on the measurement of 10 grains from a single slide (McAndrews, Berde, and Norris, 1973). It appears that there is a discrepancy between the size range of wild rice

determined by McAndrews (1969) and McAndrews, Berde, and Norris (1973). Based on 700 grains from reference slides of seven different wild rice plants, I determined the range of wild rice pollen grains to be between 28 μm and 46 μm , with an average of 35 μm and 90% confidence limits of 28 μm and 41 μm (Table 2).

Based on the small amount of data just presented, there can be quite a bit of variability in the size of wild rice pollen grains. The variation in the size of wild rice pollen grains demonstrated by the data presented here indicates that it may be hard to differentiate wild rice pollen grains from other grasses. The limited data also imply that there may be a relationship between the size of wild rice pollen grains and the environmental conditions under which they formed. It appears that the reference material collected by McAndrews (1969) at Rice Lake has a smaller size range than those collected at Big Rice Lake. If this is indeed the case, it may be very difficult to determine the presence of wild rice in a lake in the past solely on pollen grain size. In his investigation of Rice Lake, Ontario, McAndrews (1984, p. 173) based his interpretation for the expansion of wild rice on abundance rather than size, stating "... that the identity of the Gramineae pollen is a problem. The pollen is similar to wild rice in that it is relatively large with a thin, smooth wall."

In order to determine if size frequency can be used to identify wild rice in the paleoecological record with some certainty, I compared the results of the 700 measured reference wild rice pollen grains to measured grass pollen grains in the 47 surface sediment samples mentioned earlier. These samples are from 12 different wild rice lakes and 6 different non wild rice lakes.

At Big Rice Lake (Fig. 31), Cramer Lake (Fig. 35), Little Rice Lake (Fig. 66), Northern Light Lake (Fig. 66), Perch Lake (Fig. 47), Rice Portage Lake (Fig. 51), and Round Island Lake (Fig. 55), the vast majority of the measured Gramineae pollen grains fall within the 28 μm and 41 μm 90% confidence limits of the reference data. The majority of the Gramineae pollen grains in five of the six surface samples from Dumbbell Lake fall within the 90% confidence limits. The exception is the sample from deep open water, which has a very low number of grass grains (Fig. 39). A similar situation is found at Gegoka Lake. The majority of the Gramineae grains from eight of the nine samples fall within the 90% confidence limits. The exception again is the surface sediment sample from deeper open water, which has a low grass count (Fig. 43). The low Gramineae pollen counts and smaller Gramineae pollen grain size in the deep open water, may indicate that the bathymetry of the lake may play a crucial role in the deposition of wild rice pollen grains. The larger wild rice pollen grains may have a tendency to sink quickly to the lake bottom in the vicinity of the wild rice stands and become incorporated into the sediment rather than being transported to deeper water, whereas, mostly air borne regional pollen is being deposited in the deeper parts of the lake.

At Elbow Lake (Fig. 66), Moose Lake (Fig. 66), and Shannon Lake (Fig. 59), a small majority of the Gramineae grains fall within the 90% confidence limits. However, a large number also fall outside the 90% confidence limits, which indicates a lower influx of local Gramineae (wild rice) pollen.

In the non wild rice lake surface samples investigated (Cloquet, Devil Track, East Bearskin, Greenwood, Musquash, and Swamper lakes), the number of Gramineae pollen grains measured for each lake was small (5-7) and may not have yielded reliable results. However, in all of the non wild rice lake samples, the Gramineae grains fall either outside the lower end of the 90% confidence limits or within the lower one-half of the 90% confidence limits (Fig. 75).

In order to gain a more comprehensive understanding of the relative abundance of Gramineae pollen deposited within lakes with wild rice stands of varying density and coverage, pollen percentage values were determined for the same 47 surface samples used for Gramineae grain size measurements. The 12 lakes selected for this investigation display a wide range of wild rice coverage and density. Wild rice coverage on these lake ranges from small thin stands to very dense stands covering almost the entire lake. The description for coverage and density for each lake can be found under the lake's "name" followed by "Surface Sediments."

Gramineae pollen percentages are based on a pollen sum of a minimum of 400 grains of trees, shrubs, and herbs (including vascular cryptogams). Yourd (1988), essentially used the same plant groups within his pollen sum to calculate Gramineae percentage. Once the 400 grain minimum was reached the rest of transect was counted, thus completing the pollen count. The Gramineae percentage attained for each sample can be found with the grain size frequency figures for each lake. The minimum, maximum, and average Gramineae percentage is shown in Table 13.

TABLE 13. GRAMINEAE POLLEN PERCENTAGE DATA.

Lake	Minimum Gramineae Percentage	Maximum Gramineae Percentage	Average Gramineae Percentage	Number of Samples	Lake Type
Big Rice Lake	34.0	41.4	37.2	4	Rice
Cloquet Lake			1.2	1	Non Rice
Cramer Lake	19.5	28.1	23.7	4	Rice
Devil Track Lake			0.5	1	Non Rice
Dumbbell Lake	0.5	14.4	4.4	6	Rice
East Bearskin Lake			1.7	1	Non Rice
Elbow Lake			3.0	1	Rice
Gegoka Lake	1.9	13.8	6.9	9	Rice
Greenwood Lake			1.7	1	Non Rice
Little Rice Lake	8.6	15.4	12.0	2	Rice
Moose Lake			1.8	1	Rice
Musquash Lake			1.1	1	Non Rice
Northern Light Lake			3.9	1	Rice
Perch Lake	7.3	68.7	44.9	8	Rice
Rice Portage Lake	49.9	60.2	53.7	3	Rice
Round Island Lake	15.3	33.1	25.2	4	Rice
Shannon Lake	6.0	8.0	6.8	4	Rice
Swamper Lake			1.2	1	Non Rice
Combined wild rice lakes	0.5	68.7	21.5	47	Rice

According to various sources, all of the surface sediments come from wild rice lakes that are considered to have substantial enough stands to warrant harvesting, at least in good wild rice years. However, the amount of wild rice produced in a lake in any given year can vary enormously. For example, 720 kg (1,584 lbs) of wild rice was harvested from Perch Lake in 1992 and 2530 kg (5,580 lbs) in 1993 (Data provided by J.H. McMillen, 2000).

Only three of the 12 wild rice lakes investigated (Big Rice Lake, Perch Lake, and Rice Portage Lake) have Gramineae pollen percentages of 40% or over and only Perch Lake has an average Gramineae pollen percentage of 40% or greater (Table 13). Two wild rice lakes have relatively high maximum Gramineae pollen percentages of 28.1% and 33.1% (Table 13). The remaining seven of the wild rice lakes have Gramineae pollen percentages ranging from 1.8% to 15.4% (Table 13). Rice Portage Lake is the only lake investigated with multiple samples in which all of the surface sediment samples yielded Gramineae pollen percentages of 40% or greater (Fig. 51). It is apparent from the results of the surface sediment samples that lakes with harvestable quantities of wild rice can have Gramineae pollen percentages of less than 40%, even as low as 1.8%, which is equivalent to the Gramineae percentages commonly recorded in non wild rice lakes.

It is possible to infer the presence of wild rice in a lake, based on the comparison of wild rice pollen grain size distribution to Gramineae pollen grain distribution in sediment cores from wild rice lakes. However, from this data, it is not possible to ascertain that the Gramineae pollen grains are definitely those of wild rice.

There is too much overlap in the size pollen grains from various Gramineae species. From the data presented here, it is evident that harvestable quantities of wild rice can be present in a lake with very low Gramineae pollen percentages. Therefore, the only criteria that can be used to absolutely determine the presence of wild rice in the paleoecological record is wild rice macrofossils. However, in the absence of wild rice macrofossils, I believe that a combination of the percentage abundance of Gramineae pollen and Gramineae pollen grain size frequency data can be used as determining criteria to infer the presence of wild rice in the paleoecological record. The use of both Gramineae pollen grain size frequency data and Gramineae pollen percentage abundances is especially critical in sediment cores from suspected wild rice lakes that yielded low Gramineae pollen percentages. The bathymetry of the lake in question must also be taken into consideration when attempting to infer the prehistoric presence of wild rice. The data presented here indicates that Gramineae pollen abundance attributed to local influx from the wild rice is more likely to be recovered from shallow water locations. Based on the currently available data, it is not possible at this time to determine with any certainty the quantity of wild rice available in a lake in the past.

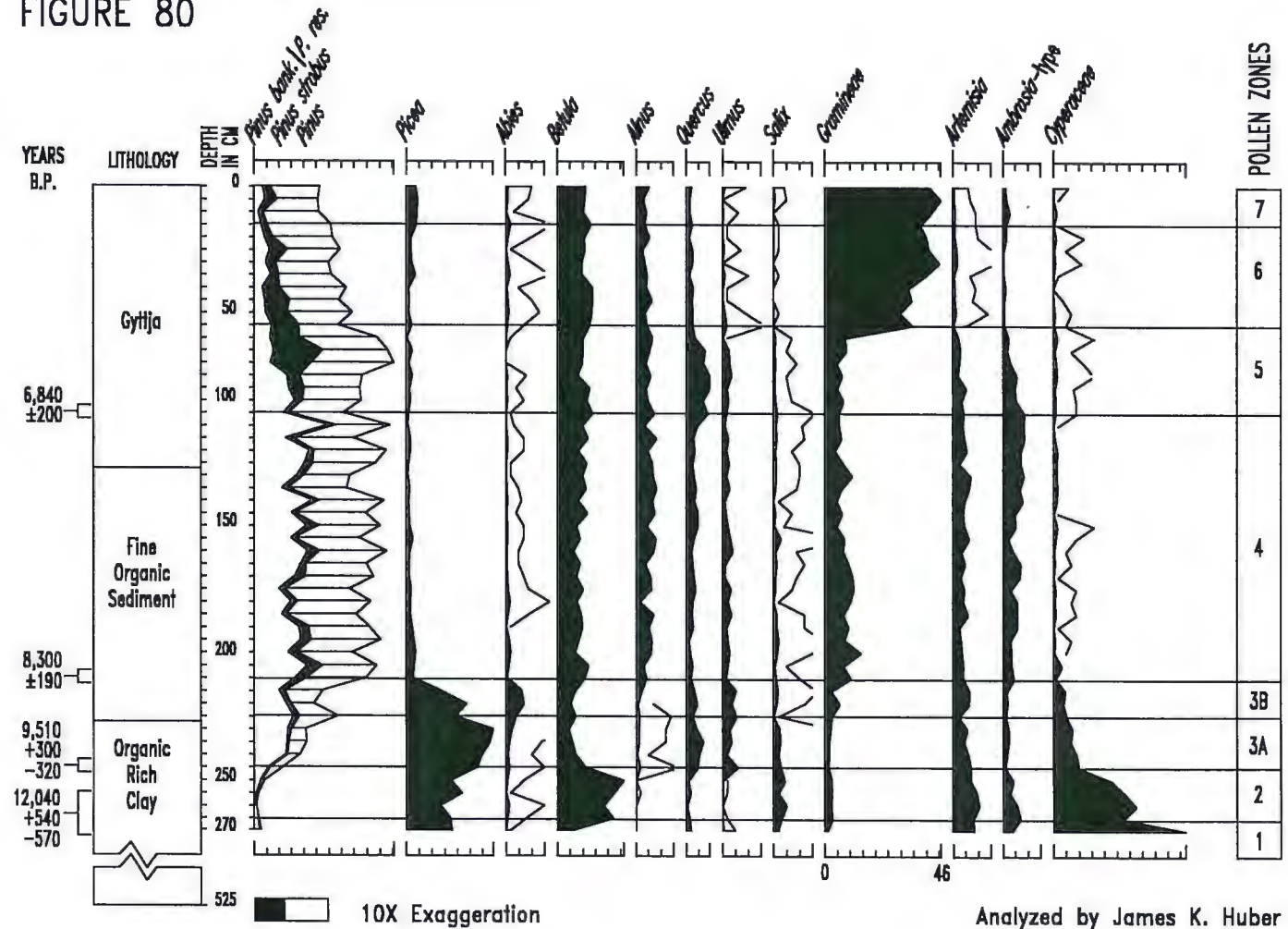
POLLEN EVIDENCE FOR WILD RICE AT THREE STUDY LAKES

Big Rice Lake

In the Big Rice Lake pollen diagram, Zone BRL-6 is characterized by a dramatic increase in Gramineae pollen. Gramineae pollen increases abruptly from 8% at the top of Zone BRL-5 to 35% at the bottom of Zone BRL-6 (Fig. 80). The increase in Gramineae is attributed to an expansion of wild rice (*Zizania aquatica*) in the lake. There is no date on the increase in Gramineae from the core. However, the major increase in the Gramineae pollen profile is estimated to date at 3,670 years ago based on sediment accumulation rates.

Wild rice was probably present in Big Rice Lake prior to the major increase in Gramineae pollen. Gramineae values, for the most part, fluctuate between 7% and 14% (Fig. 80), in Zone BRL-4. The increase in prairie-type plants in this zone is interpreted as indicating a lowering of lake level during the Hypsithermal (8,000-4,000 yr B.P.). At the beginning of Zone BRL-4, the sediment depth is 210 cm. A small drop in the water level would greatly increase the available area conducive for the growth of wild rice in Big Rice Lake, which is a flat-bottomed shallow basin. Wild rice grows best in lakes with a water depth of 0.3 m to 1.5 m and seldom thrives in water depth of over 2 m (Vennum, 1988). The consistently high values of Gramineae in Zone BRL-4 could very well indicate the establishment and expansion of wild rice in the shallower parts of the lake. In many of the lakes in northeast Minnesota, Gramineae values are 3% or less throughout the Hypsithermal. During the Hypsithermal, Gramineae values are less than 3% at Weber Lake (Fries, 1962),

POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
 BIG RICE LAKE
 ST. LOUIS COUNTY, MINNESOTA
 FIGURE 80

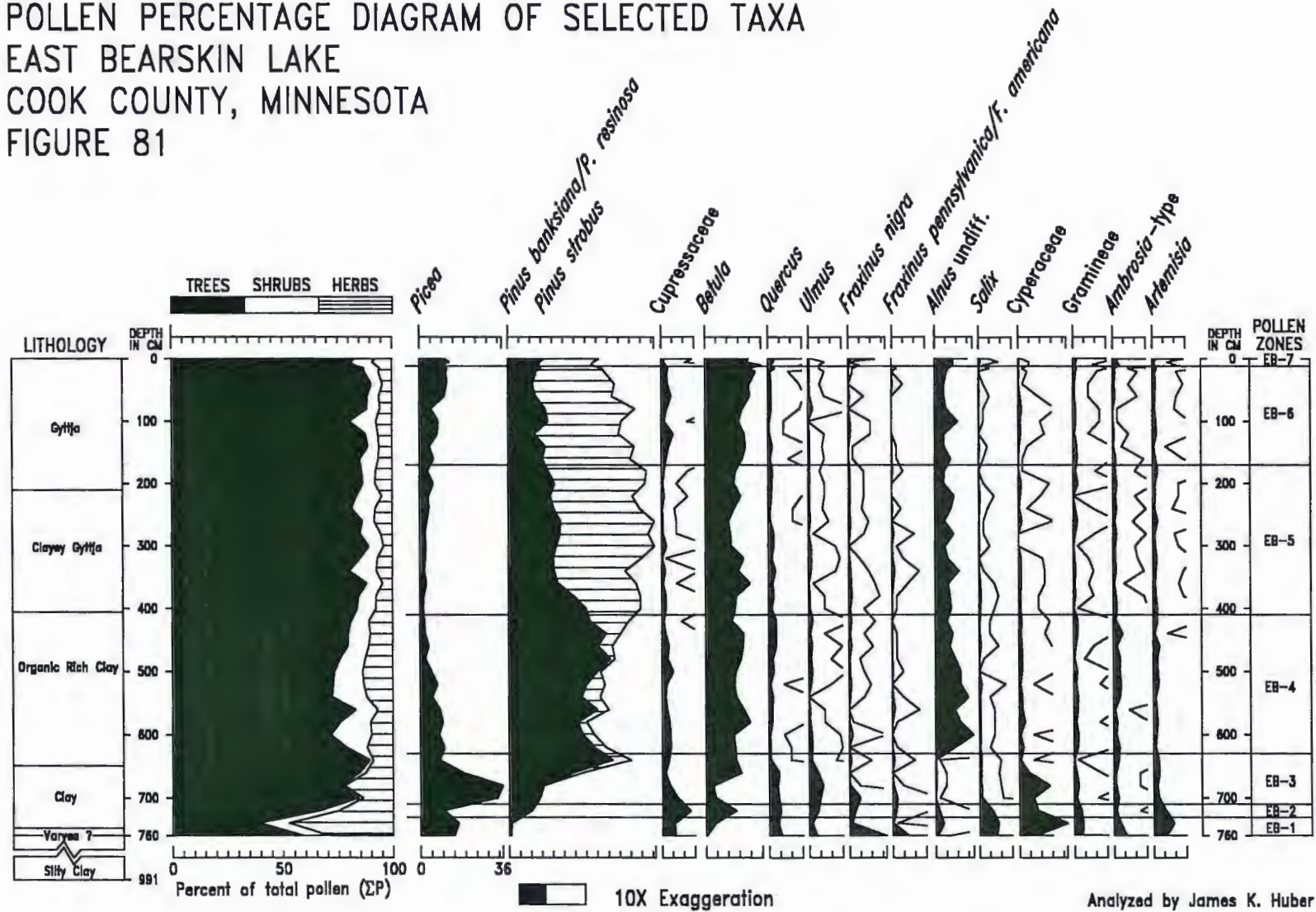


and peak at 5% in two levels at Kotiranta Lake (Wright and Watts, 1966).

Gramineae values are also less than 3% at Cloquet Lake (Plate 4), and East Bearskin Lake (Fig. 81). East Bearskin Lake shows a typical Gramineae profile for a non wild rice lake.

Substantiating the somewhat elevated Gramineae percentages in Zone BRL-4 as indicating the presence of wild rice is the Gramineae pollen grain size frequencies (Fig. 82). Zone BRL-4 begins at 210 cm in the core. Between 230 cm and 210 cm, there is a shift in the size frequency of Gramineae pollen grains. At the 230 cm level, the majority of the Gramineae pollen grains are smaller than 28 μm the lower limit of the 90% confidence limits established for the wild rice reference grains (Fig. 82) indicating the presence of grasses other than wild rice. At 210 cm, the majority of the Gramineae pollen grains fall within the 90% confidence limits established for the wild rice reference grains indicating the presence of wild rice (Fig. 82). Based on the Gramineae size frequency data, wild rice had probably become established in Big Rice Lake approximately 8,300 yr B.P. before climatic warming was in full effect. The Gramineae size frequency data also indicate that Big Rice Lake probably supported wild rice continuously from 8,300 yr B.P. until the present.

POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
EAST BEARSKIN LAKE
COOK COUNTY, MINNESOTA
FIGURE 81



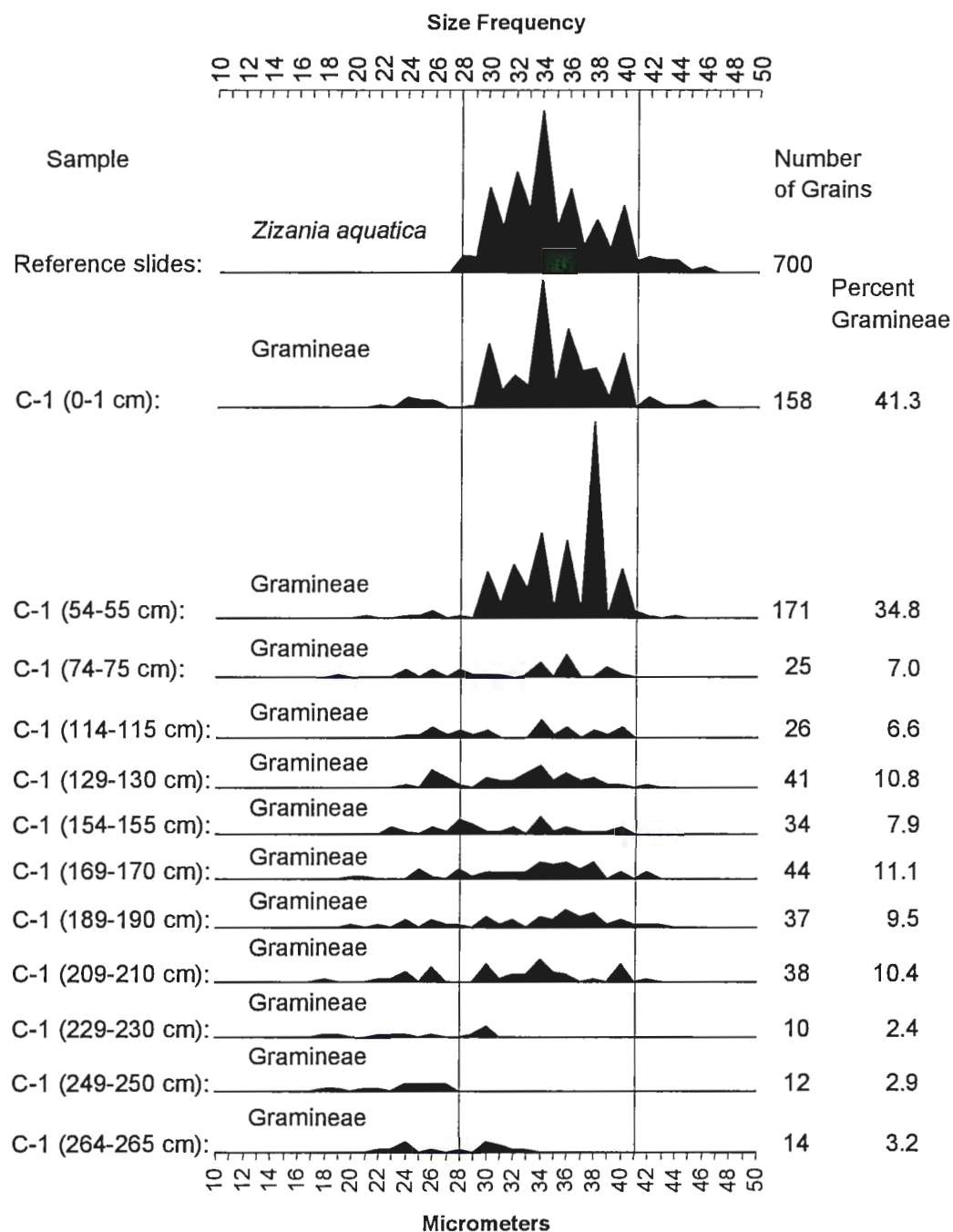


Figure 82. Comparison of *Zizania aquatica* (wild rice) with fossil Gramineae pollen grain size distributions of sselected levels from Big Rice Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

The decrease in Gramineae values in Zone BRL-5 (Fig. 80) probably represents the return of cooler and moister conditions at the end of the Hypsithermal. At this time the water level in Big Rice Lake probably increased, reducing the area conducive for wild rice growth. However, Gramineae values remain higher (4-8%) than those commonly found for this time period in northeast Minnesota. For this time period at Weber Lake (Fries, 1962) and East Bearskin Lake (Fig. 81), Gramineae values are 1-2% and reach a maximum of 5% at Cloquet Lake (Plate 4).

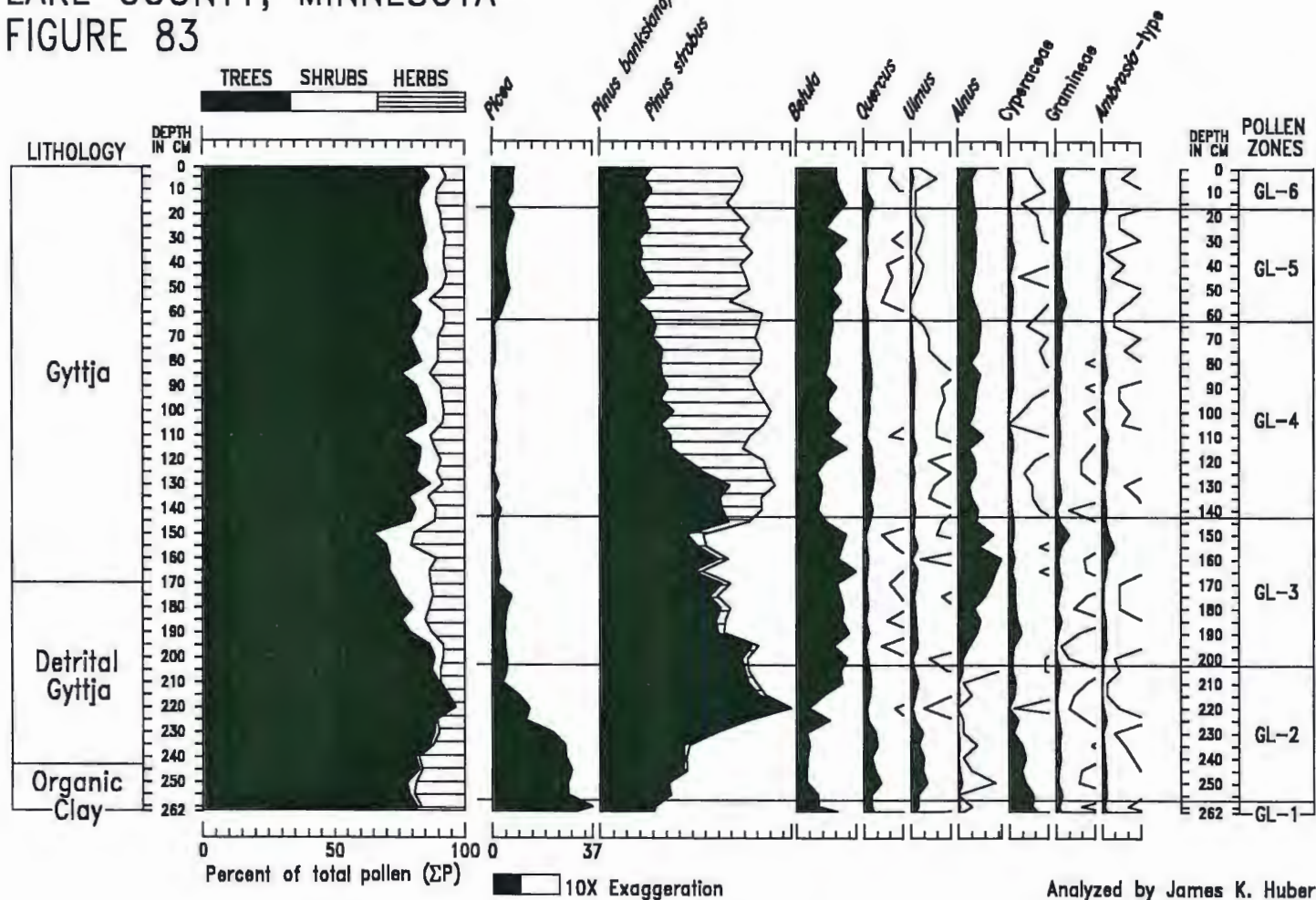
As sediment continued to infill Big Rice Lake, reducing the water level, wild rice was able to expand very quickly over most of the lake, at the beginning of Zone BRL-6 (Fig. 80) from 8% to 35%. At the time of coring, the water depth at the coring location was one meter. Currently the water depth over most of Big Rice Lake is approximately 1-1.3 m. The major increase in the Gramineae pollen profile starts at 55 cm below the water/sediment interface at the time of coring (Fig. 80) and is accompanied by the vast majority of the Gramineae pollen grains falling within the 90% confidence limits established for the reference data (Fig. 82). Based on this information, the approximate depth of Big Rice Lake at the time of the Gramineae rise began was between approximately 1.5 m and 1.8 meters, the optimal depth for wild rice growth.

Gegoka Lake

In the Gegoka Lake pollen diagram, a small increase in Gramineae occurs in Zone GL-6 (Fig. 83). Gramineae values increase from 2.2% at the top of Zone GL-5 to 5.2% at the beginning of Zone GL-6 and falling to 3.6% at the top of the core. *Ambrosia*-type percentages increase slightly from the previous zone. Gramineae concentration is greater than in any of the previous zones, ranging from 3,775 grains/cm³ to 21,575 grains/cm³ of wet sediment. *Ambrosia*-type concentration is 1,290 grains/cm³ at the top of Zone GL-5, increases to 9,240 grains/cm³ at the bottom of Zone GL 6, then declines to 3,340 grains/cm³ at the surface. Although the surface sample Gramineae value is low in the core sample, the surface samples from other locations within Gegoka Lake have higher values, as high as 13.8% (Fig. 43).

The small increase in Gramineae pollen is attributed to the expansion of wild rice which is currently growing over much of Gegoka Lake. The increase in Gramineae abundance is much lower than that found at other rice lakes currently supporting substantial stands of wild rice. The Gramineae pollen data suggest that the *Zizania aquatica* population may have expanded during Zone GL-6 as infilling of the lake created more favorable habitat and that the presence of wild rice in Gegoka Lake is a historic event, assuming the small *Ambrosia*-type pollen rise is associated with the advent of Euro-American settlement about 1890 (Maher, 1977). There is limited information that the Civilian Conservation Core (CCC) tried to establish rice in lakes in this area in the 1930's, (S.L. Mulholland, personal communication, 1994), Gegoka Lake was probably one of these lakes. New Gramineae pollen grain size distribution

POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
GEGOKA LAKE
LAKE COUNTY, MINNESOTA
FIGURE 83



data for a few selected levels in the pollen core, suggests an alternative interpretation. The Gramineae pollen grain size distribution data indicate that wild rice may have been established in the lake by about 7,000 years ago when white pine invaded the area. About one-half of the Gramineae pollen grains from the 150 cm level fall within the 90% confidence limits of the wild rice reference data (Fig. 84). This new interpretation is somewhat tenuous because Gramineae pollen grain size distribution information is only available for four levels from the entire core at this time. Subsequent analysis of the Gramineae grain size distribution in the Gegoka Lake core may reinforce the revised interpretation for the establishment of wild rice in the lake.

Shannon Lake

Pollen has been counted for the uppermost four samples of a 790 cm core recovered from the central portion of Shannon Lake and the lowermost 90 cm of the core (Huber, in press). Gramineae pollen only accounts for about 6% of the pollen recovered in the uppermost four levels (Fig. 85). Shannon Lake has a maximum depth of less than 6 m, with much of the lake having a depth of greater than 3 m. The 54.66 ha lake has approximately 10 ha of wild rice growing in small stands in shallows and bays. Marquette Pond, a 13 ha lake in Beltrami County, Minnesota also contains approximately 10 ha of wild rice beds (Yourd, 1988). The Gramineae value in the uppermost pollen samples at Marquette Pond are approximately 45% (Yourd, 1988). Although the beds of wild rice in Shannon Lake are approximately equal in size to those of Marquette Pond, the Shannon Lake wild rice beds only make

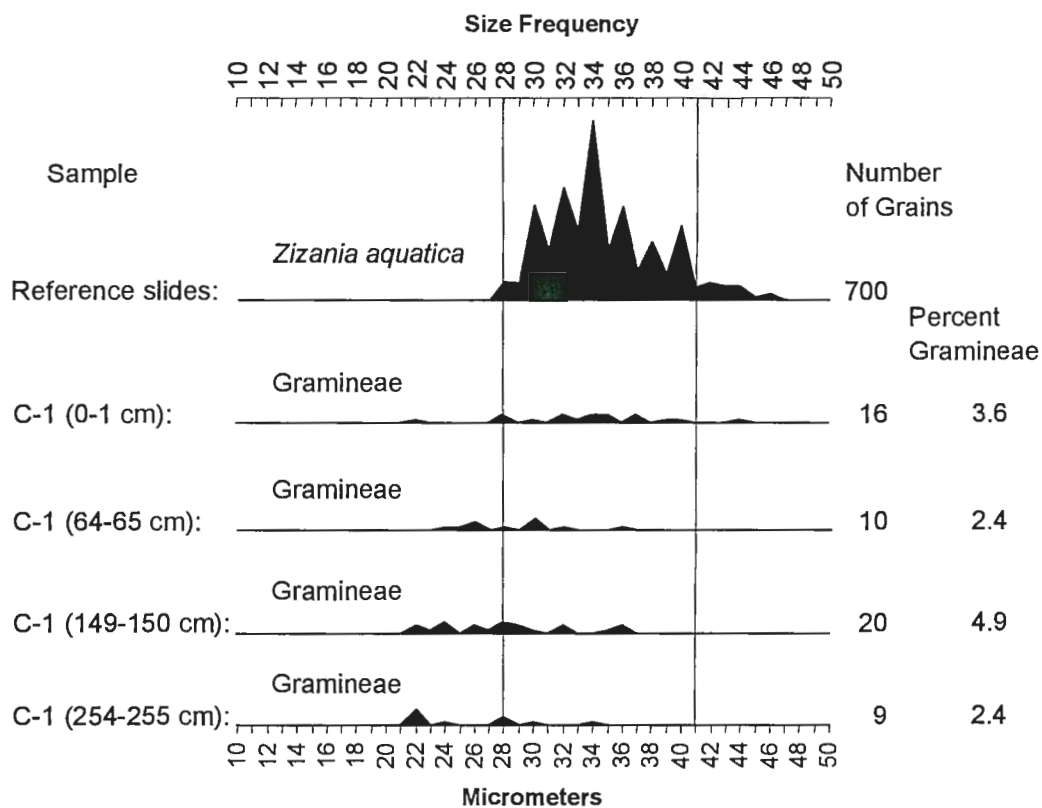
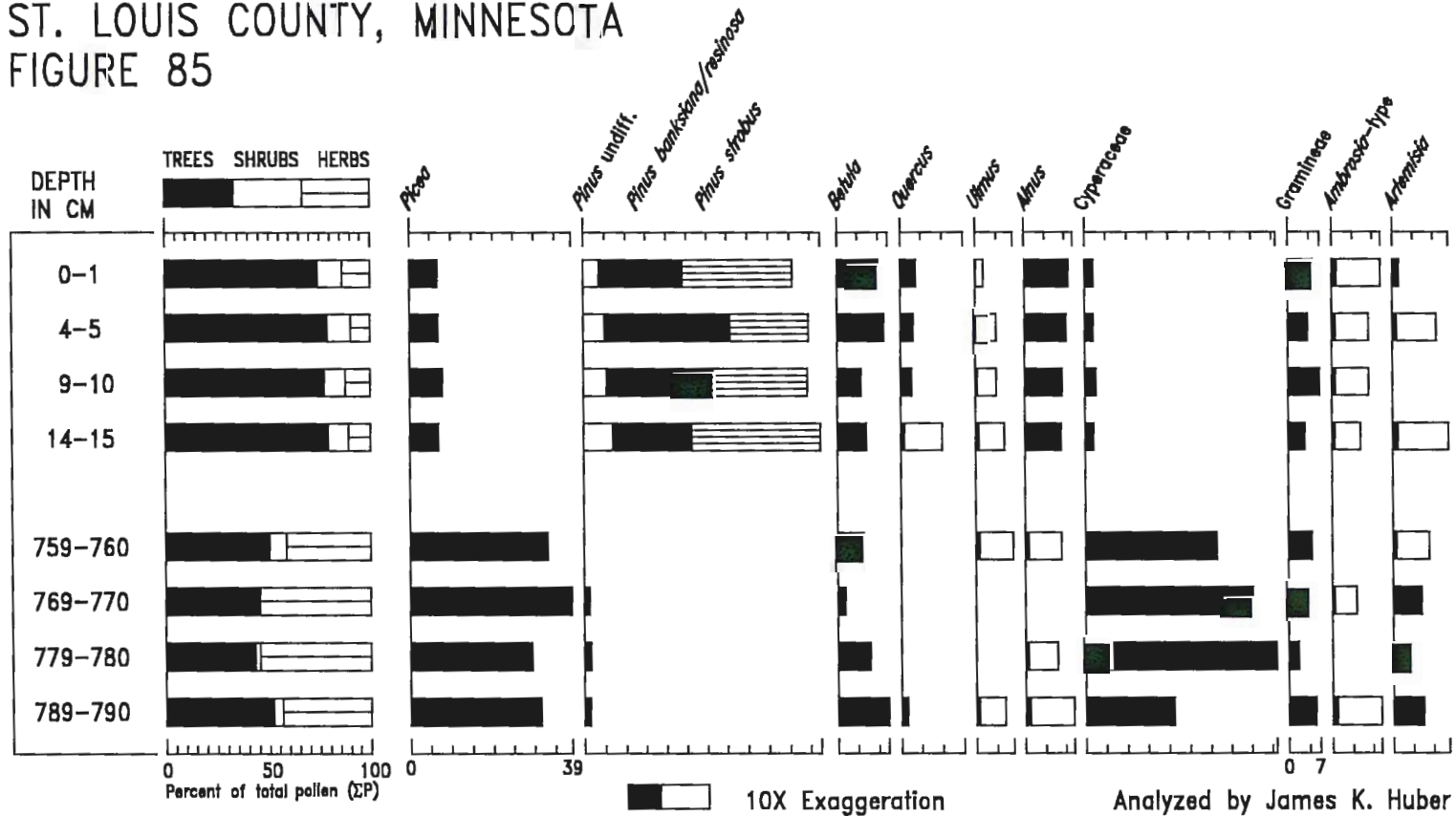


Figure 84. Comparison of *Zizania aquatica* (wild rice) with fossil Gramineae pollen grain size distributions of selected levels from Gegoka Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA
SHANNON LAKE
ST. LOUIS COUNTY, MINNESOTA
FIGURE 85



up one-fifth of the area of the lake. The low value of Gramineae pollen in Shannon Lake indicates that local influx of wild rice pollen is being dampened by regional pollen influx. The dampening effect appears to be caused by the low wild rice stand to lake basin ratio. The Gramineae pollen data from Shannon Lake suggest that substantial beds of wild rice occurring in bays and shallows of large lakes in the past may not be reflected in the pollen record based on Gramineae pollen percentages alone.

The Gramineae pollen grain size distribution data for Shannon Lake indicate that the majority of the Gramineae pollen is probably derived from wild rice (Fig. 86). The majority of the Gramineae pollen grains in the upper four levels fall within the 90% confidence limits of the reference data for wild rice. When the Gramineae pollen grain size distribution data from the upper four levels is compared to four levels from near the base of the core, one can see that there has been a significant shift in Gramineae grain size distribution between the early states of lake development and the present (Fig. 86).

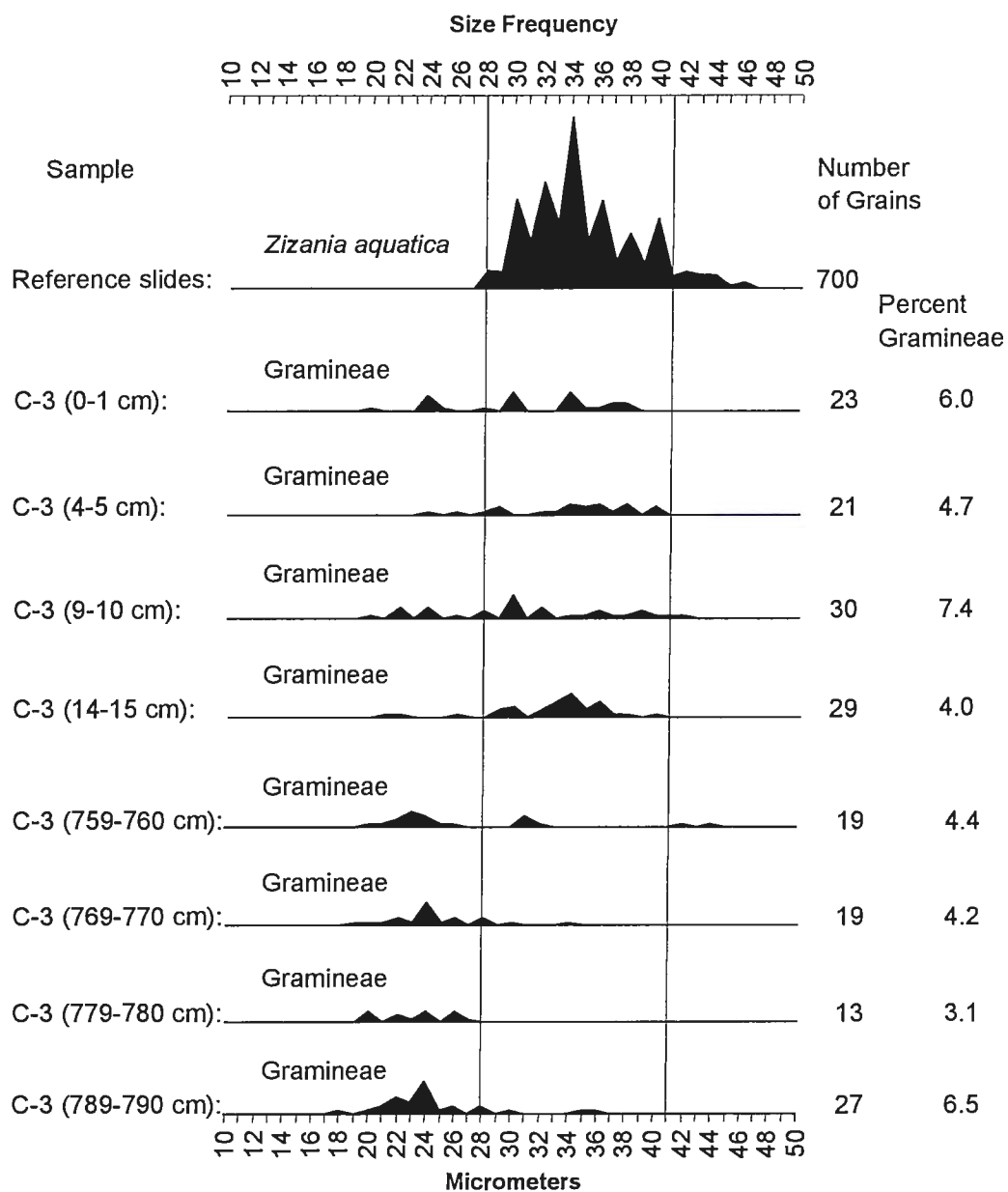


Figure 86. Comparison of *Zizania aquatica* (wild rice) with fossil Gramineae pollen grain size distributions of surface selected levels from Shannon Lake. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

Discussion

Pollen evidence for the presence of wild rice in the Big Rice, Gegoka, and Shannon lake cores is derived from both Gramineae abundance and grain size distribution. At Big Rice Lake the low but somewhat elevated Gramineae percentage values and the Gramineae grain size distribution data indicate that wild rice probably was established in the lake by 8,300 yr B.P. At Gegoka Lake the criteria produce conflicting interpretations, the Gramineae percentage data suggests that wild rice was probably established only recently in the lake, but the, preliminary Gramineae grain size distribution data indicate that wild rice may have been established in the lake about 7,000 years ago when white pine migrated into the area. The hypothesis that low Gramineae percentage values in wild rice lakes similar to Shannon Lake, may not reflect substantial beds of wild rice occurring in bays and shallows of lakes with relatively large expanses of open water too deep to support wild rice is substantiated by the Gramineae grain size distribution data which indicate the presence of wild rice in Shannon Lake. Gramineae percentage abundance data may be a poor indicator of the presence of wild rice, in lakes that were prehistorically only partially covered with wild rice. It appears that Gramineae grain size distribution is a better indicator of wild rice in this type of lake in the paleoecological record.

WILD RICE LAKE RESERVOIR: A TEST LAKE

A preliminary investigation of Wild Rice Lake Reservoir was undertaken in order to test the criteria put forth to identify wild rice lakes in the paleoecological record. Wild Rice Lake Reservoir is a lake that is known historically to have supported a substantial bed of wild rice over much of its surface, and no longer supports wild rice because of a rise in water level as a result of damming. With its known history, Wild Rice Lake Reservoir provides an excellent opportunity to test criteria for the identification of a past wild rice lake in the paleoecological record.

Wild Rice Lake was modified in the 1920's when the Great Northern Power Company constructed dams and dikes in the area to generate hydroelectric power (Rapp, 1995). As part of the hydroelectric power project, a dam was built at the north end of the lake creating what is now known as Wild Rice Lake Reservoir. Mulholland and others (1990) report that Native Americans came to Wild Rice Lake to gather wild rice and plums prior to construction of the dam. With construction of the dam, the water level in the lake was raised, effectively killing off the wild rice. Currently Wild Rice Lake Reservoir does not support any major stands of wild rice. However, I have, over the past 20 years, observed a few wild rice plants near the boat landing adjacent to the dam at the north end of the lake. This locality is outside the original shoreline of Wild Rice Lake. Wild rice has also been reported as growing to a very limited extent at the mouth of a stream on the northwest side of the reservoir (E. Dahl, personal communication, 1990). Wild Rice Lake Reservoir is located in sections 25, 26, T51N, R15W of the Duluth Heights 7.5' quadrangle and

sections 7, 18, 19, 30, T51N, R14W and sections 12, 13, 14, 23, 24, 25, 26, T51N, R15W of the Fredenberg 7.5' quadrangle. Location data for the Wild Rice Lake Reservoir long core (Fig. 87) is shown in Table 14.

TABLE 14. WILD RICE LAKE RESERVOIR CORE LOCATION DATA.					
Sample	XUTM	YUTM	Sample Type	Depth (m)	Date
C-1	562272	5193200	Livingstone	2.35	14 March 1999

Loss-On-Ignition of Organic Carbon and Carbonate

Organic carbon content and carbonate content for the complete core is shown in Figure 88. There is a marked change in organic carbon at the 75 cm level (Fig. 88). Below 75 cm organic carbon is 5% or less, above 75 cm, organic carbon ranges from 20% to 49%. There is also a slight increase in carbonate above the 75 cm level, however carbonate content is low throughout the core, 4% or less (Fig. 88). The dramatic change in carbonate content at the 75 cm level correlates well with the sediment composition of the core, below 75 cm, the sediment is mineralgenic and above 75 cm the core is gyttja. Pollen is poorly preserved in the mineral rich sediment and well preserved above. Based on the abrupt sediment change and the preservation and composition of the pollen, it appears that a major hiatus occurs in the core at 75 cm. The hiatus is probably the result of the shallow Wild Rice Lake drying up during the Hypsithermal.

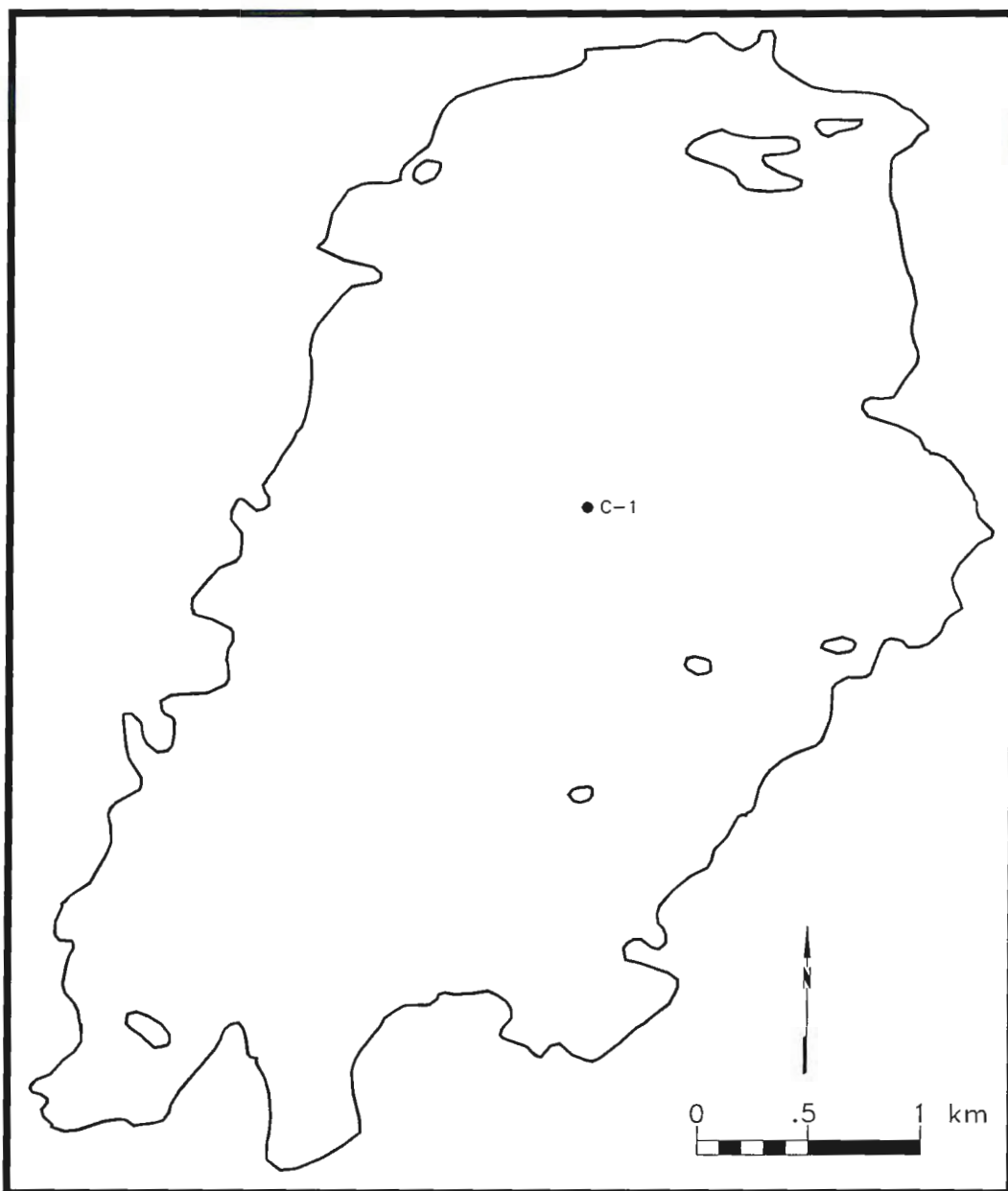
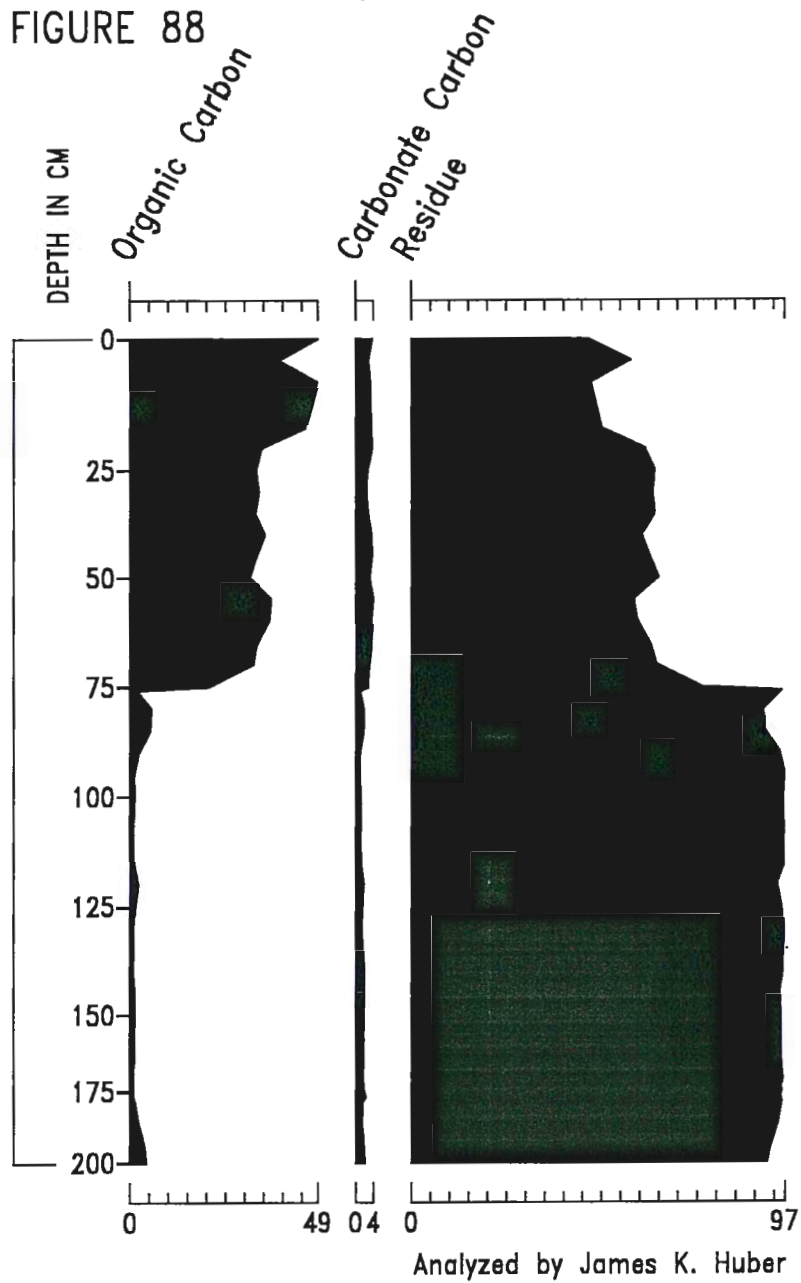


Figure 87. Map of approximate sample location at Wild Rice Lake Reservoir Lake.

LOSS-ON-IGNITION PERCENTAGE DIAGRAM
 WILD RICE LAKE RESERVOIR
 ST. LOUIS COUNTY, Minnesota
 FIGURE 88



Pollen Spectra

Arboreal pollen dominates the pollen spectra of the Wild Rice Lake Reservoir core and consists mostly of *Picea*, *Pinus*, *Betula*, and *Alnus* in the upper three levels analyzed (Fig. 89). *Picea* is more abundant in 74-75 cm level than the upper three levels. Gramineae pollen percentages range from 10.3% to 16.6% in the upper three levels and is only 1.15 in the 74-75 cm level (Fig 89).

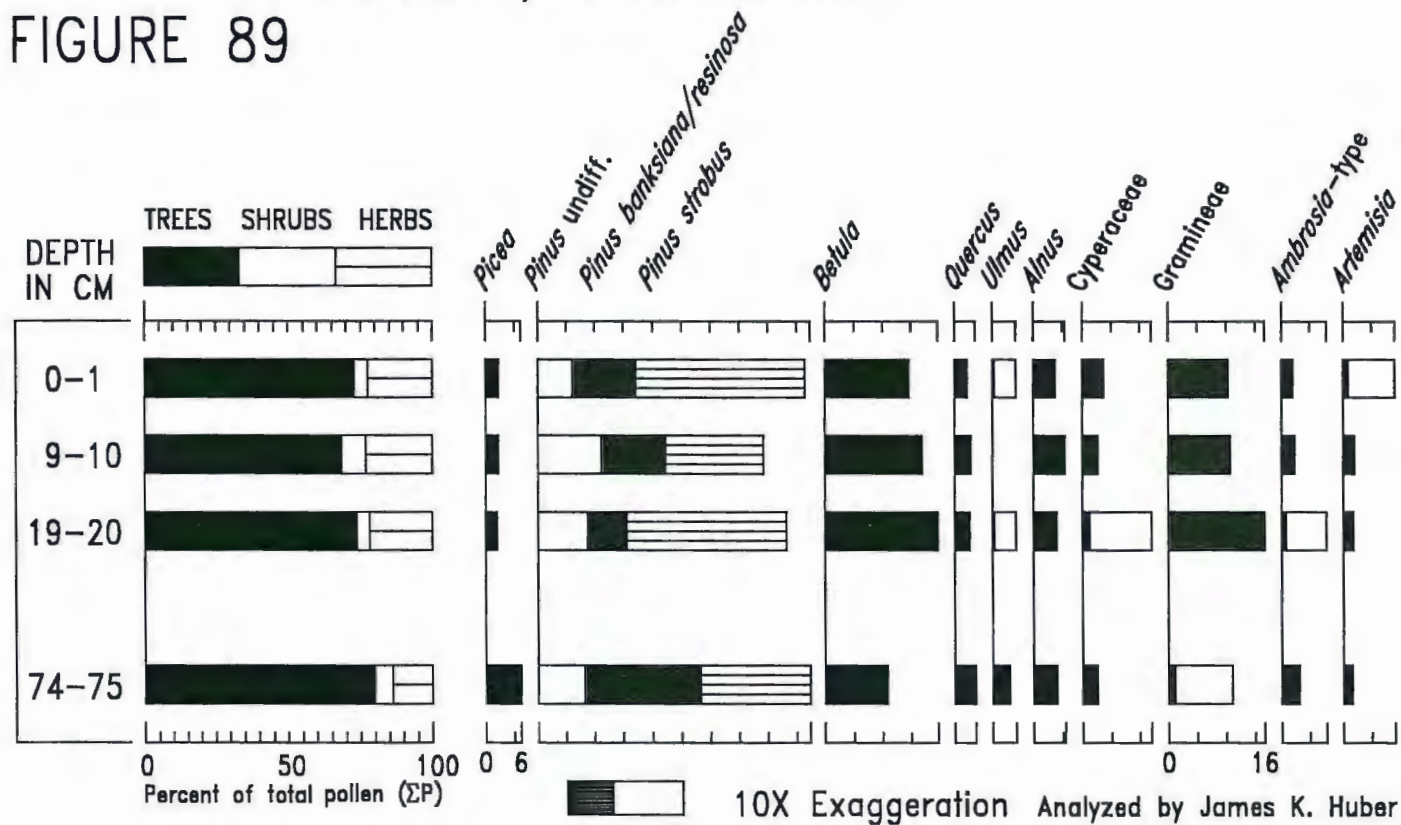
Discussion

In order to ascertain if wild rice was at one time present in Wild Rice Lake Reservoir, three criteria can be used: the presence of wild rice macrofossils, Gramineae pollen abundance, and Gramineae pollen grain size distribution. At this time, macrofossil analysis has not been undertaken, so this option is not viable. That leaves only two criteria that can be tested: Gramineae pollen abundance and Gramineae pollen grain size distribution.

Gramineae pollen percentages for the upper three levels are, somewhat, but not substantially higher (10.3-16.6%) than those found in the surface samples (0.5-1.7%) from non wild rice lakes (Table 13) and are not even close to the 40% put forth by Yourd (1988) to indicate the presence of a harvestable stand of wild rice. The Gramineae percentage value at 74-74 cm is very similar to those recorded at non wild rice lakes such as Cloquet and East Bearskin Lakes (Plates 4 and 8). If it was not known from historical records that Wild Rice Lake Reservoir was once a major

POLLEN PERCENTAGE DIAGRAM OF SELECTED TAXA WILD RICE LAKE RESERVOIR ST. LOUIS COUNTY, MINNESOTA FIGURE 89

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wild ricing lake, it probably would not be identified as a wild rice lake based solely on Gramineae pollen abundance in the paleoecological record.

However, if one looks at the Gramineae pollen grain size, one finds a major shift in Gramineae pollen grain size distribution between the 74-75 cm level sample and the upper three samples (Fig. 90). In the 74-75 cm level none of the Gramineae pollen grains fall within the 90% confidence limits established for the *Zizania aquatica* reference data, but in the upper three levels most of the Gramineae pollen grains do (Fig. 90). The Gramineae pollen grain size distribution data indicate that sometime between the 74-75 cm level and the 19-20 cm, wild rice became established in the original Wild Rice Lake. When wild rice became established in the lake, within this 55 cm interval, will require further pollen analysis.

Based on the Gramineae pollen data from the Wild Rice Lake Reservoir core, one can see that using the Gramineae abundance criterion alone, that a historically known past wild rice lake would not have been identified in the paleoecological record based on the standard methods currently being used. The Gramineae pollen data from the Wild Rice Lake Reservoir also indicate the importance of using Gramineae pollen grain size distribution in conjunction with Gramineae pollen abundance to ascertain the possible presence of wild rice in lakes where Gramineae percentage are low to moderate.

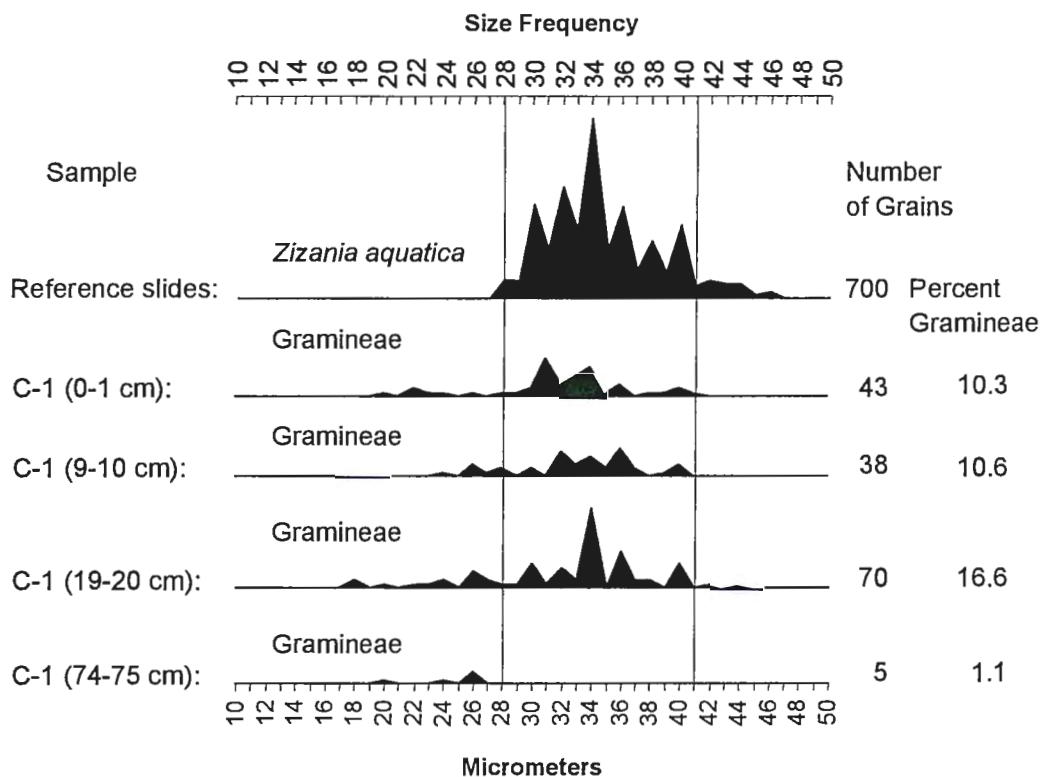


Figure 90. Comparison of *Zizania aquatica* (wild rice) with fossil Gramineae pollen grain size distributions of selected levels from Wild Rice Lake Reservoir. Vertical bars indicate 90% confidence limits for 700 reference wild rice pollen grain size measurements. Gramineae pollen percentages are also shown.

HISTORY OF WILD RICE IN MINNESOTA

Based on the available pollen data the earliest occurrence of wild rice in Minnesota is from Wolf Creek (Fig. 19) between 10,000 and 9,000 yr B.P. (Fig. 91). Before 10,000 yr B.P., the Gramineae pollen profile values are less than 10%. Just after 10,000 yr B.P., Gramineae values begin to increase reaching approximately 50% at 9,500 yr B.P. By 9,200 yr B.P., Gramineae values decline to 30% Wolf Creek (Birks, 1976).

Between 9,000 and 7,000 yr B.P., no pollen data are available that indicate Gramineae abundances of 40% in any currently analyzed cores. However, at Big Rice Lake (Fig. 19) Gramineae range from 7% to 14% between 8,300 yr. B.P. and 6,800 yr B.P. indicating that small stands may have been available (Fig. 91). Based on Gramineae pollen grain size frequencies (Fig. 82), it is quite likely that wild rice had become established in Big Rice Lake by approximately 8,300 yr B.P.

By 7,000 yr B.P. Gramineae abundance at Rossburg Bog (Wright and Watts, 1969) had reached 10% and increased to 40% by approximately 6,200 yr B.P. (Fig. 91). Based on the increase in Gramineae at Rossburg Bog (Fig. 19), there is a good possibility that by approximately 6,500 yr B.P. wild rice was established in the basin and available in small harvestable quantities. By 6,200 yr B.P., extensive wild rice stands may have been established at Rossburg Bog based on the greater than 40% Gramineae values in the pollen profile (Fig. 91). At Gegoka Lake, Gramineae pollen grain size distribution data indicate that wild rice may have been established in the by about 7,000 yr B.P. when white pine migrated into the area (Fig. 84).

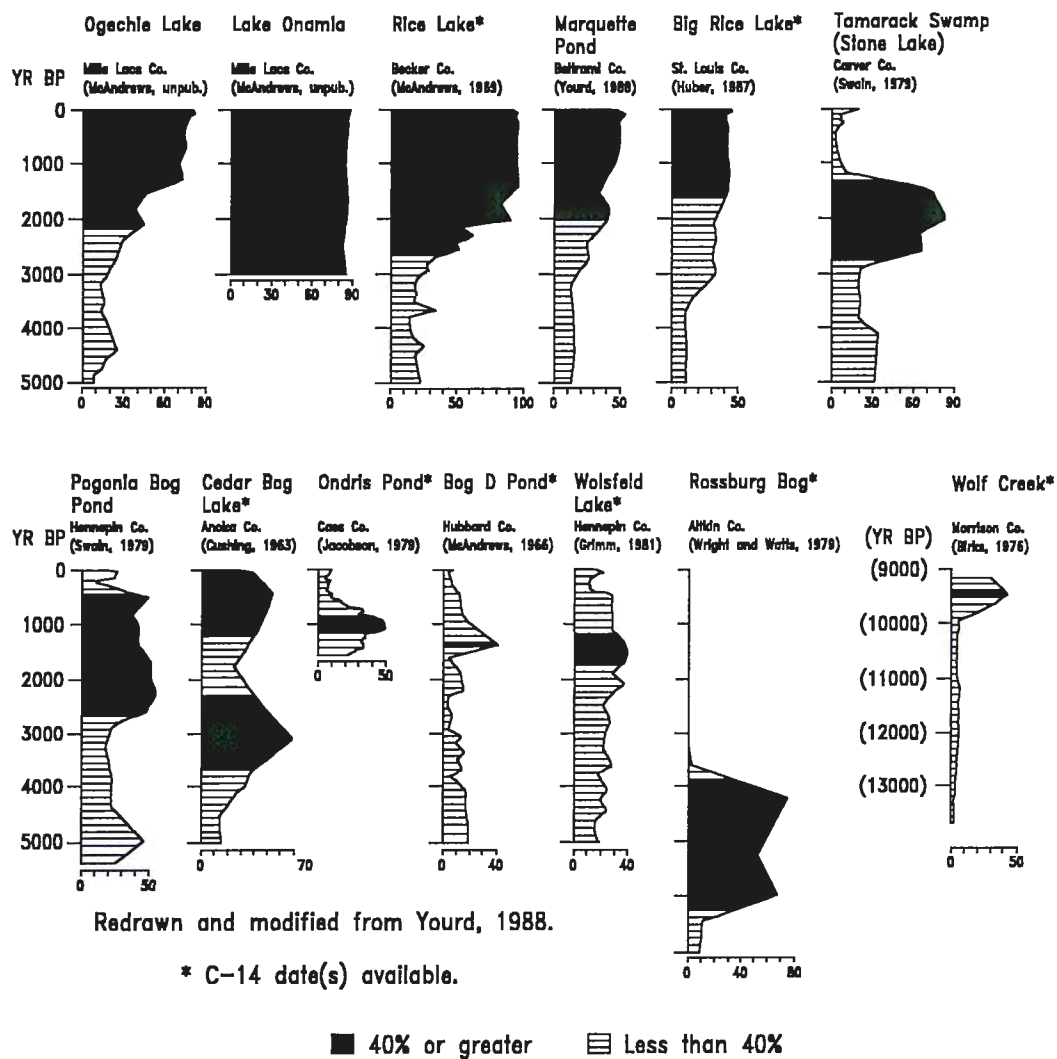


Figure 91. Gramineae pollen profiles from selected sites in Minnesota.

At approximately 5,000 yr B.P., Gramineae had attained values of at least 13% at Pogonia Bog Pond (Swain, 1978), 30% at Tamarack Swamp (Swain, 1978), and 20% at Wolsfeld Lake (Grimm, 1981). Between the confluence of the Minnesota and Mississippi Rivers in southeast Minnesota, Gramineae attains 12% at Rice Lake (McAndrews, 1969) by this time (Fig. 91). By approximately 5,000 yr B.P., Gramineae values are 20% at Bog D Pond (McAndrews, 1966) and 12% at Marquette Pond (Yourd, 1988) in the vicinity of the Mississippi Headwaters and 10% at Big Rice Lake in central St. Louis County, northeast Minnesota (Fig. 91). Gramineae values are greater than 40% at Rossburg Bog (Wright and Watts, 1969) and 10% at Ogechie Lake (McAndrews unpublished in Yourd, 1988). The Gramineae percentage values from available pollen cores suggest that by 5,000 yr B.P. wild rice had probably become established, to some extent, in suitable lakes along the Mississippi River and in northeast Minnesota (Fig. 19).

Between 5,000 and 4,000 yr B.P. there is a Gramineae maximum at Ogechie Lake, of approximately 22% (McAndrews unpublished in Yourd, 1988), Rice Lake of approximately 21% (McAndrews, 1969), Tamarack Swamp of approximately 32% (Swain, 1978), and Wolsfeld Lake of approximately 12% (Grimm, 1981). Gramineae values decline at Pogonia Bog Pond to about 20% (Swain, 1978) and remain stable at Marquette Pond (Yourd, 1988), Big Rice Lake (4-8%), and Bog D Pond (McAndrews, 1966). The Gramineae values from the pollen cores (Fig. 19) and the Gramineae pollen grain size distribution data (Fig. 82) indicate the possibility of at least small harvestable stands of wild rice in these lakes. At Gegoka Lake, where

Gramineae values are below 5%, Gramineae pollen grain size distribution data (Fig. 84), indicate the possible presence of presence of wild rice.

Gramineae values decline at Ogechie Lake (McAndrews unpublished in Yourd, 1988), Tamarack Swamp (Swain, 1978), and Pogonia Bog Pond (Swain, 1978); and fluctuate at Bog D Pond (McAndrews, 1966) and Wolsfeld Lake (Grimm, 1981) between 4,000 and 3,000 yr B.P. (Fig. 91). Except for a peak at approximately 3,000 yr B.P., the Gramineae values are generally lower at Rice Lake (McAndrews, 1969) than between 5,000 and 4,000 yr B.P. (Fig. 91). At Marquette Pond (Yourd, 1988) and Big Rice Lake, Gramineae values begin to increase during this time period (Fig. 91). By approximately 3,600 yr B.P., wild rice values had reached 35% at Big Rice Lake, indicating the presence of a significant stand of wild rice. Gramineae increases to 70% at Cedar Bog Lake (Cushing, 1963) by approximately 3,100 yr B.P. (Fig. 91). The high Gramineae values at Cedar Bog Lake suggest that a large stand of wild rice became established between 4,000 and 3,000 yr B.P. At Rossburg Bog (Wright and Watts, 1969), Gramineae values decline to trace amounts by approximately 3,800 yr B.P. (Fig. 91). The lower Gramineae values at Ogechie Lake (McAndrews unpublished in Yourd, 1988), Rice Lake (McAndrews, 1969), Tamarack Swamp (Swain, 1978), and Pogonia Bog Pond (Swain, 1978) and the fluctuating Gramineae values at Bog D Pond (McAndrews, 1966) and Wolsfeld Lake (Grimm, 1981) may be related to an increase in water levels and available moisture at the end of the Hypsithermal when climatic conditions ameliorated. With cooler, moister

climatic conditions and more available moisture, the lowering of Gramineae pollen values may reflect a rise in lake level.

By 3,000 yr B.P. Gramineae pollen values at the base of the Lake Onamia sequence (McAndrews unpublished in Yourd, 1988) had already reached almost 90% (Fig. 91). Between 3,000 yr B.P. and 2,000 yr B.P., Gramineae values reach at least 40% at Ogechie Lake (McAndrews unpublished in Yourd, 1988), Rice Lake (McAndrews, 1969), Tamarack Swamp (Swain, 1978), and Pogonia Bog Pond (Swain, 1978). At Marquette Pond (Yourd, 1988) and Big Rice Lake Gramineae values are approaching 40% (Fig. 91). By 2,000 yr B.P., Gramineae values are declining at Cedar Bog Lake (Cushing, 1963). A small Gramineae maxima occurs at both Bog D Pond (McAndrews, 1966) and Wolsfeld Lake (Grimm, 1981) at approximately 2,000 yr B.P. (Fig 91).

By 1,000 yr B.P., Gramineae values drop to less than 10% at Tamarack Swamp (Swain, 1978). At Bog D Pond (McAndrews, 1966) and Wolsfeld Lake (Grimm, 1981), Gramineae values have reached a maximum of 40% and begun to decline by 1,000 yr B.P. (Fig. 91). The basal Gramineae value at Ondris Pond (Jacobson, 1979) is approximately 20% at 1,500 yr B.P. (Fig. 91) and reaches a maximum of 50% at 1,000 yr B.P. before declining. Gramineae values are at least 40% (Fig. 91) between 2,000 yr B.P. and 1,000 yr B.P. at Ogechie Lake (McAndrews unpublished in Yourd, 1988), Lake Onamia (McAndrews unpublished in Yourd, 1988), Rice Lake (McAndrews, 1969), Marquette Pond (Yourd, 1988), Big Rice Lake, and Pogonia Bog Pond (Swain, 1978). After a minimum at approximately

1,800 yr B.P. at Cedar Bog Lake (Cushing, 1963), Gramineae values again reach at least 40% by 1,000 yr B.P. (Fig. 91).

From 1,000 yr B.P. to the present (Fig. 91), Gramineae has maintained values of at least 40% at Ogechie Lake (McAndrews unpublished in Yourd, 1988), Lake Onamia (McAndrews unpublished in Yourd, 1988), Rice Lake (McAndrews, 1969), Marquette Pond (Yourd, 1988), Big Rice Lake, and Cedar Bog Lake (Cushing, 1963). At Pogonia Bog Pond (Swain, 1978) and Ondris Pond (Jacobson, 1979) Gramineae values decline to less than 40% (Fig. 91). At Tamarack Swamp (Swain, 1978), Pogonia Bog Pond (Swain, 1978), Ondris Pond (Jacobson, 1979), Bog D Pond (McAndrews, 1966), and Wolsfeld Lake (Grimm, 1981) Gramineae values decline to about 10% before increasing to about 18% at the top of the pollen sequence (Fig. 91).

At Shannon Lake, which currently supports stands of wild rice in several bays and shallow areas, the uppermost lake sediments have a Gramineae pollen percentage value of less than 8%. Gramineae pollen grain size distribution data (Fig. 86) also indicate the presence of wild rice in the upper sediments of Shannon Lake. Further analysis of the Shannon Lake core is needed to determine the history of wild rice in the lake. There is small maxima in Gramineae pollen (5.2%) in the uppermost zone at Gegoka Lake (Zone GL-6) which currently supports a large stand of wild rice. Zone 6 is associated with the advent of Euro-American settlement and deforestation in the area indicating that the Gramineae pollen maxima occurred after 1820. However, as mentioned earlier, the Gramineae pollen grain size distribution data indicate that

wild rice may have been established in Gegoka Lake by about 7,000 yr B.P. when white pine migrated into the area (Fig. 84).

Currently, the history of wild rice in Minnesota is based, for the most part, on the Gramineae abundance. Subsequent investigations of Gramineae profiles using the criterion of Gramineae pollen grain size distribution, as well as, Gramineae abundance and macrofossil analysis will enhance the understanding of the history and availability of wild rice in Minnesota.

WHAT CONSTITUTES A WILD RICE LAKE: PAST AND PRESENT

The limited paleoecological and archaeological literature currently available, that deals with the history and expansion of wild rice, show no consensus on what constitutes a wild rice lake past or present. The criteria for what constitutes a wild rice lake appears to be dependent on the nature of the investigation being undertaken.

A very broad interpretation of what constitutes a wild rice lake is currently being used by the Minnesota Wild Rice Management Planning Project, Bois Forte Band of Minnesota Chippewa. The Minnesota Wild Rice Management Planning Project personnel are currently compiling an inventory of all modern wild rice lakes in Minnesota. Their definition of what constitutes a modern wild rice lake is a lake in which wild rice has been reported to have grown historically (J. Ridbauer, personal communication, 2000). Using this criterion, the reported presence of one wild rice plant on a lake, constitutes that lake as a wild rice lake.

This broad approach is very useful for lake management and planning, but does not address the issue of harvestable stands. However, without knowing the individual history of each lake, a lake that currently supports a few wild rice plants may very well have been an important lake for the harvesting of wild rice in the past. This scenario is documented for Wild Rice Lake Reservoir (this study). Using a broad definition as defined by the Bois Forte Band of Minnesota Chippewa, is also very useful when dealing with ceded land treaties with Native Americans in Minnesota.

According to Ojibwe elder J.C. McMillen (personal communication, 2000), a good rice lake is one from which 160 kg (350 lbs) can be harvested per day.

However, J.C. McMillen (personal communication, 2000), also relates that what constitutes a wild rice lake depends on wild rice production and availability in any given year and that there is no hard and fast rule on what constitutes a wild rice lake.

In the archaeological literature, a lake is inferred to be a wild rice lake if it currently supports wild rice, or if there is archaeological evidence, such as ricing jigs, that indicate that the lake has supported wild rice in the past. G.R. Peters (personal communication, 2000) reports that there are archaeological sites that indicate the harvesting of wild rice in the Superior National Forest on lakes that currently do not support any wild rice.

Yourd (1988), uses the a Gramineae abundance value of 40%, based on a total pollen count to indicate the presence of harvestable quantities of wild rice in a lake in the past. He also indicates that wild rice may be present in a lake that has Gramineae values of less than 40%. McAndrews (1969) used both high Gramineae abundance and Gramineae pollen grain size data to delineate the expansion of wild rice in Rice Lake, Becker County, Minnesota, but only used Gramineae abundance to infer the expansion of wild rice in Rice Lake, Ontario (McAndrews, 1984). However, the use of 40% Gramineae abundance to indicate the presence of harvestable stand of wild rice appears to be too high. The Gramineae abundance data from several of the lakes investigated in this study, have very low (Moose Lake: 1.8%) to moderate (Wild

Rice Lake Reservoir: 16.6%) amounts of Gramineae pollen and are or were within the recent history, harvestable wild rice lakes.

Based on the Gramineae abundance and Gramineae pollen grain size data presented here and in the literature, it is not possible at this time to derive any definite criteria to determine what constitutes a wild rice lake in the past. One reason for this is the limitation of the paleoecological data. In the absence of the direct evidence of wild rice in the form of macrofossils, the presence of wild rice can only be inferred from the pollen data. Wild rice is a grass and the pollen of wild rice is similar in size and surface sculpturing to most other grass pollen and cannot be identified to species with absolute certainty. However, using a Gramineae abundance in conjunction with, Gramineae pollen grain size frequency data it appears to be possible to infer the past presence of wild rice in a lake, although it is not possible to assess the relative density and extent of the prehistoric rice bed.

The determination of what actually constitutes a wild rice lake either in the past or present appears to be highly dependant on the nature of the questions being asked. If one is dealing with territories ceded by Native Americans, the presence of even minimal amounts of wild rice may have major legal and ethical ramifications. Also, the minimal presence of wild rice on a lake may be important in the planning and management of a lake by conservation officials. In the paleoecological record, what constitutes a prehistoric wild rice lake or inferred prehistoric wild rice lake is dependent on the presence of wild rice macrofossils, Gramineae abundance, or Gramineae pollen grain size frequency data.

POTENTIAL FOR THE USE OF WILD RICE AS A FOOD SOURCE PRIOR TO THE WOODLAND PERIOD

The expansion of wild rice in Minnesota is commonly associated with the harvesting of wild rice and the advent of ceramics in the Woodland Period (2,500-400 yr B.P.) during the late Holocene. The Woodland Tradition is commonly defined by three traits: pottery, burial mounds, and horticulture (Stevenson and others, 1997; Anfinson and Wright, 1990; Gibbon, 1986; Mason, 1981). The construction of pottery and burial mounds indicate an increase in population and may reflect the utilization of wild rice as a major food source (Dawson, 1983; Rajnovich, 1984; Peters and Motivans, 1985; Lofstrom, 1987). Horticulture had not been established in northeast Minnesota; however a quasi-agriculture became established around the harvesting of wild rice (Mason, 1981). It is becoming generally accepted, as evidence for its use by Native Americans accumulates (Johnson, 1969a; 1969b; Gibbon, 1976; Peters and Motivans, 1984; Valppu, 1989; Valppu and Rapp, 2000), that wild rice was a major form of subsistence in northeast Minnesota during the Woodland Period (Gibbon and Caine, 1980; Lofstrom, 1987; G.R. Peters, personal communication, 2000). It is known that Native Americans in the Great Lakes Region were highly dependent on wild rice as a major food source in early historic times (Jenks, 1900; Densmore, 1928; Vennum, 1988). Gibbon and Caine (1980) postulate that a much larger population may have occurred in the northern part of the state than in the southern quarter where maize horticulture existed. Gibbon and Caine (1980) also note that many of the St. Croix burial sites are located by lakes that have extensive stands of wild rice today. However, there is little evidence for the use of

wild rice in the Archaic, and none for the Paleoindian. Ford and Brose (1975) report the presence of a few charred wild rice grains in association with a Late Archaic or Early Woodland cremation burial in Michigan. At the McIntyre Site in Ontario, the Archaic use of wild rice is suspected, but has not been proven (McAndrews, 1984).

Indirect methods such as pollen analysis must be employed to demonstrate the potential use of wild rice prior to the Woodland Period where direct evidence for the utilization of wild rice is currently lacking. Basing the presence of prehistoric harvestable quantities of wild rice in a lake solely on the abundance of Gramineae pollen has its limitations. Shannon Lake, (see Pollen Evidence for Wild Rice at Three Study Lakes), is a 55 ha lake has about 10 ha of wild rice beds as does Marquette Pond, a 13 ha lake in Beltrami County, Minnesota. The Gramineae values in the uppermost pollen samples from Marquette Pond are approximately 45% (Yourd, 1988) and are approximately 6% at Shannon Lake, although the beds of wild rice are approximately equal in size. The initial results from the Shannon Lake data suggest that harvestable stands of wild rice occurring in bays and shallows of lakes that have areas too deep to support wild rice may not be reflected in the pollen record.

On the other hand, as demonstrated when basing the interpretation solely on Gramineae abundance, as originally done for Gegoka Lake pollen diagram, lakes that currently contain large stands of wild rice may not have a very long history. Although Gramineae pollen grain size distribution infers that wild rice may have been present in Gegoka Lake as early as 7,000 yr B.P., this new interpretation awaits verification.

Even though the data from Gegoka Lake indicate that it may have a long history of wild rice production, the Gegoka Lake data implies that it is necessary to know the history of a current wild rice lake before using it in regional archaeological studies of past settlement patterns and subsistence availability. It is quite possible that a lake currently supporting wild rice may not have a long history of wild rice production.

Based on the profiles with greater than 40% Gramineae pollen, it appears that wild rice was present in harvestable quantities at various times in the last 10,000 years and available, to some extent, during all archaeological periods (Fig. 92). Most of the available data indicate that wild rice has become more abundant in the late Holocene during the Woodland Period. However, this evidence may be the result of site selection and interpretation of the Gramineae pollen profiles rather than the prehistoric abundance of wild rice. Most palynological studies in which a Gramineae rise is attributed to the expansion of wild rice were not undertaken to investigate wild rice but were paleoecological investigations to reconstruct vegetational change in the area and it was just by chance that the evidence for the presence of wild rice was found. Sites that have been investigated specifically to understand the history of wild rice have been undertaken at lakes that currently support large stands of wild rice rather than at locations that may have supported wild rice prior to the Woodland Period. Many lakes in the past probably were capable of supporting harvestable quantities of wild rice. However, as sediment continued to infill these lakes they became bogs and were no longer able to support wild rice. Wolf Creek, Roszburg Bog, Bog D Pond, Ondris Pond, and Pogonia Bog Pond are all examples of this.

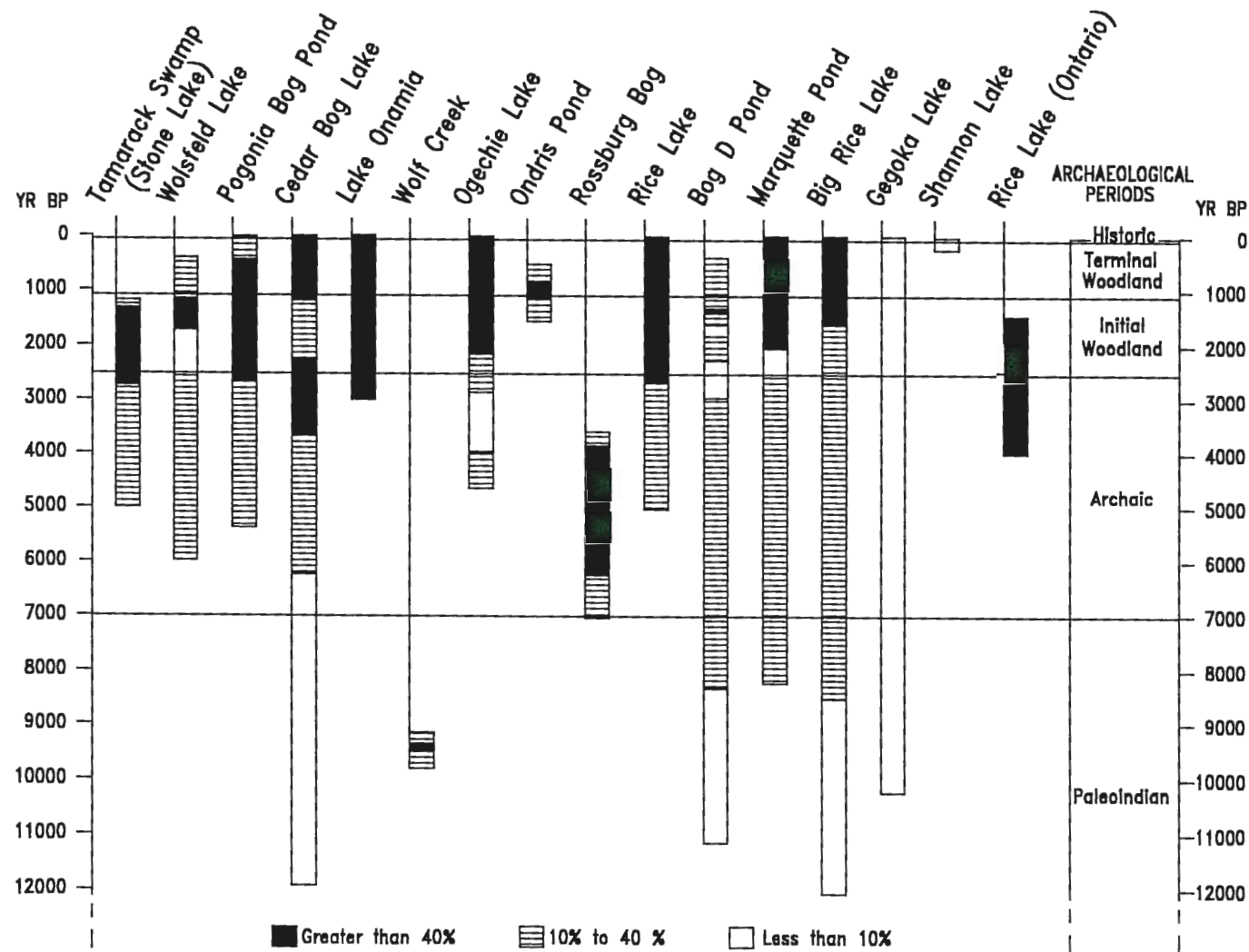


Figure 92. Gramineae pollen sequences from selected sites in Minnesota and Ontario

When looking for evidence for the prehistoric occurrences of wild rice, it is also necessary to understand the past hydrology and morphology of the basin. During the Hypsithermal, data indicate that the water levels in some lakes may have dropped by as much as 6 m (Anderson, 1993). Pollen and seed data indicate that lake level fell in many lakes during the Hypsithermal but did not dry out completely (Wright, Winter, and Patten, 1963, Watts and Winter, 1966; Janssen, 1968; Van Zant, 1979). Wild Rice Lake Reservoir, St. Louis County, Minnesota, is a fairly large shallow lake that supported wild rice until the early 1900's when it was damned for hydroelectric power. Preliminary analysis of a core from the lake indicates that it dried out completely during the early Holocene (see Wild Rice Lake Reservoir: A Test Lake). Either a rise or fall in lake level would change the morphometry of a lake. Evidence indicates that many lakes may have suffered a drop in lake level during the Hypsithermal, that would have reduced the potential acreage for wild rice. At the same time, a drop in water levels in deeper lakes may have actually increased available habitat for wild rice.

The current palynological evidence based on Gramineae abundance indicates that wild rice became more abundant during the Woodland Period (Fig. 91). However, a closer look at the available palynological data suggests that wild rice may have been more abundant in the Middle to Late Archaic than previously thought.

Wild rice was probably present in the shallows in many of the wild rice lakes investigated prior to its expansion over most of the lake. At Shannon Lake, wild rice is growing in large stands in the bays and shallows and the uppermost lake sediments

have a Gramineae pollen percentage values of about 6% (Fig. 86). The presence of the Woodland ricing site indicates that harvestable quantities existed on the lake even though the Gramineae abundance values are low, less than 10%. Therefore wild rice was probably present in quantities large enough to provide a major food source on some lakes even though Gramineae abundance values are less than 40%.

Based on the Gramineae abundance and grain size distribution data from Shannon Lake, even lakes with less than 10% Gramineae pollen values may have appreciable stands of wild rice. If one looks at the pollen profiles in which Gramineae percentage abundance is between 10% and 40%, wild rice was probably present in quantities large enough to provide a considerable subsistence component throughout most of the Archaic Period and part of the Paleoindian Period (Fig. 92). The data base currently available is not large enough to infer the time of arrival of wild rice in northeast Minnesota or when wild rice was available in large enough quantities to provide an important addition to the subsistence base. The earliest record of wild rice is from the near the Mississippi River at Wolf Creek between 9,550 yr B.P. (Fig. 93). At 7,000 yr B.P., wild rice was probably abundant at Rossburg Bog near the Mississippi River and had most likely become established in Big Rice Lake by 8,300 yr B.P. using the 10% to 40% values to infer the presence of wild rice (Fig. 92) and the Gramineae pollen grain size distribution data (Fig. 82). Wild rice may have been present in Marquette pond as early as 8,000 yr B.P. based on 10% to 40% Gramineae and Gramineae pollen grain size distribution data (Fig. 79). Gramineae pollen grain size distribution data indicate that wild rice may

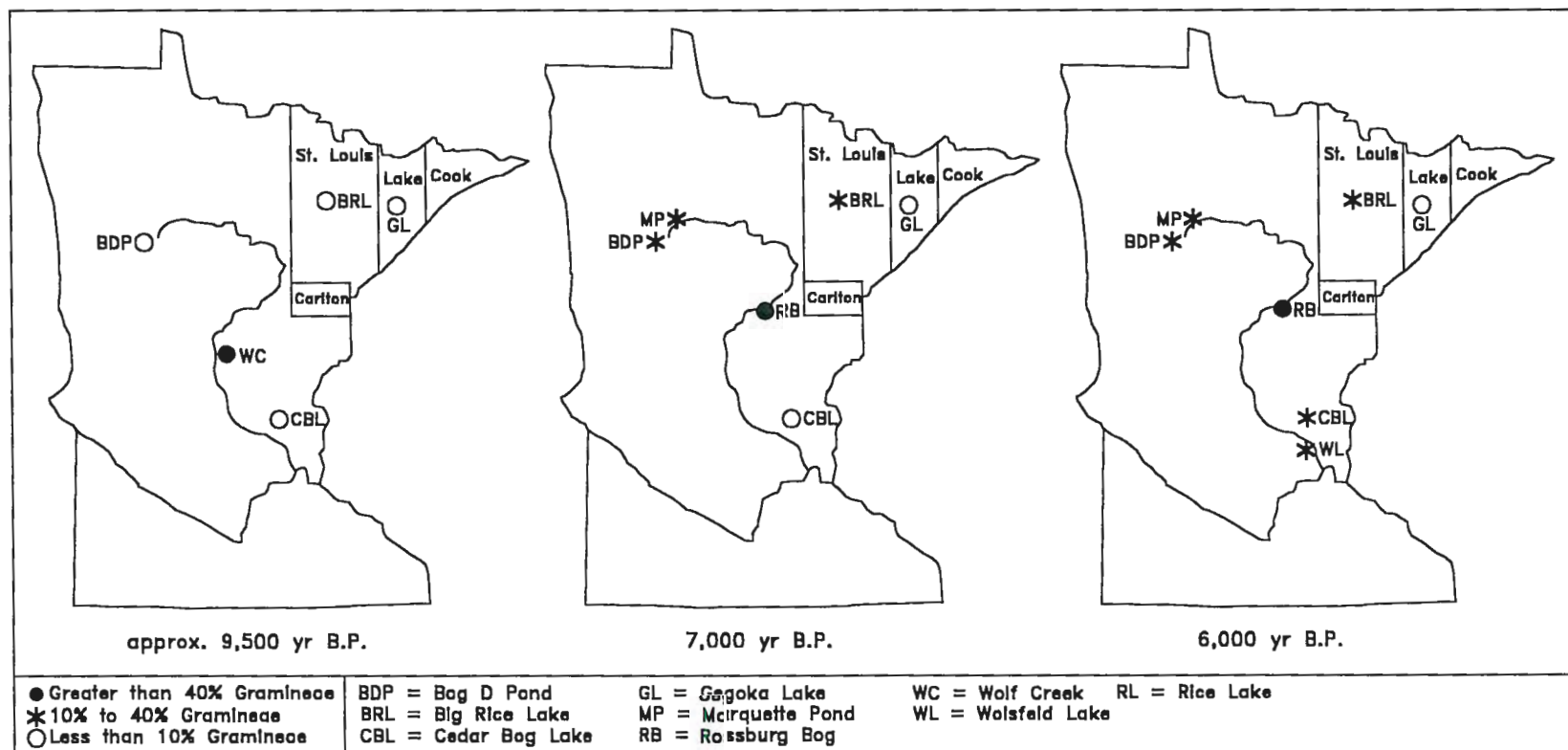


Figure 93. Location map of Gramineae rise pollen sites in Minnesota: 9,500 yr B.P.–6,000 yr B.P.

have been present in Gegoka Lake at early as 7,000 years ago (Fig. 84). Wild rice is near the headwaters of the Mississippi River and the confluence of the Minnesota River by 7,000 yr B.P. (Fig. 93). At 6,000 yr B.P., Wolsfeld Lake may have wild rice. By 4,000 yr B.P., there is a slight expansion of wild rice in east-central Minnesota (Fig. 94). No expansion of major wild rice localities appears to have occurred by 3,000 yr B.P. (Fig. 94). At 2,000 yr B.P., several sites indicate an increase in the abundance of wild rice to over 40% (Fig. 95) which is maintained until the present. Dates indicating the intensive use of wild rice lake range from approximately 2,000 yr B.P. to 600 yr B.P. (Rapp, Allert, and Peters, 1990; Valppu and Rapp, 2000).

The palynological data discussed here, indicate that wild rice was present at Wolf Creek and Big Rice Lake, and may have been present at Bog D Pond and Marquette Pond during the Late Paleoindian, and infers that wild rice was probably present in several lakes throughout most of the Archaic based on the 10% to 40% Gramineae abundance data (Fig. 92). In light of the Gramineae pollen grain size distribution data presented in this study for Big Rice Lake, Gegoka Lake, Shannon Lake, and Wild Rice Lake Reservoir, the viability for using the 10% to 40% Gramineae abundance data to indicate the presence of harvestable stands of wild rice is much more valid. However, in lakes where Gramineae pollen grain size distribution data are not available, using the 10% to 40% Gramineae abundance data to indicate the presence of harvestable stands of wild rice is still tenuous.

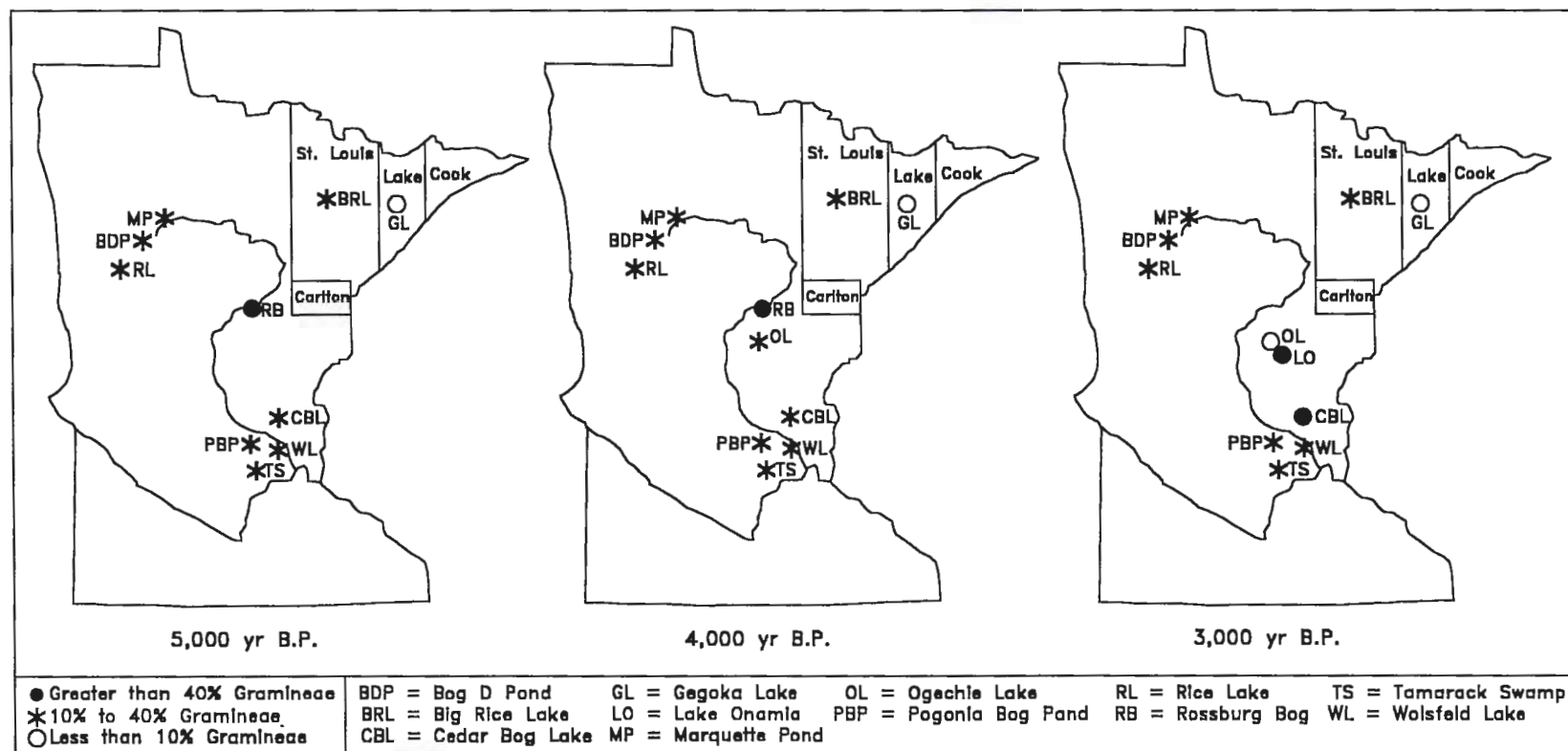


Figure 94. Location map of Gramineae rise pollen sites in Minnesota: 5,000 yr B.P.—3,000 yr B.P.

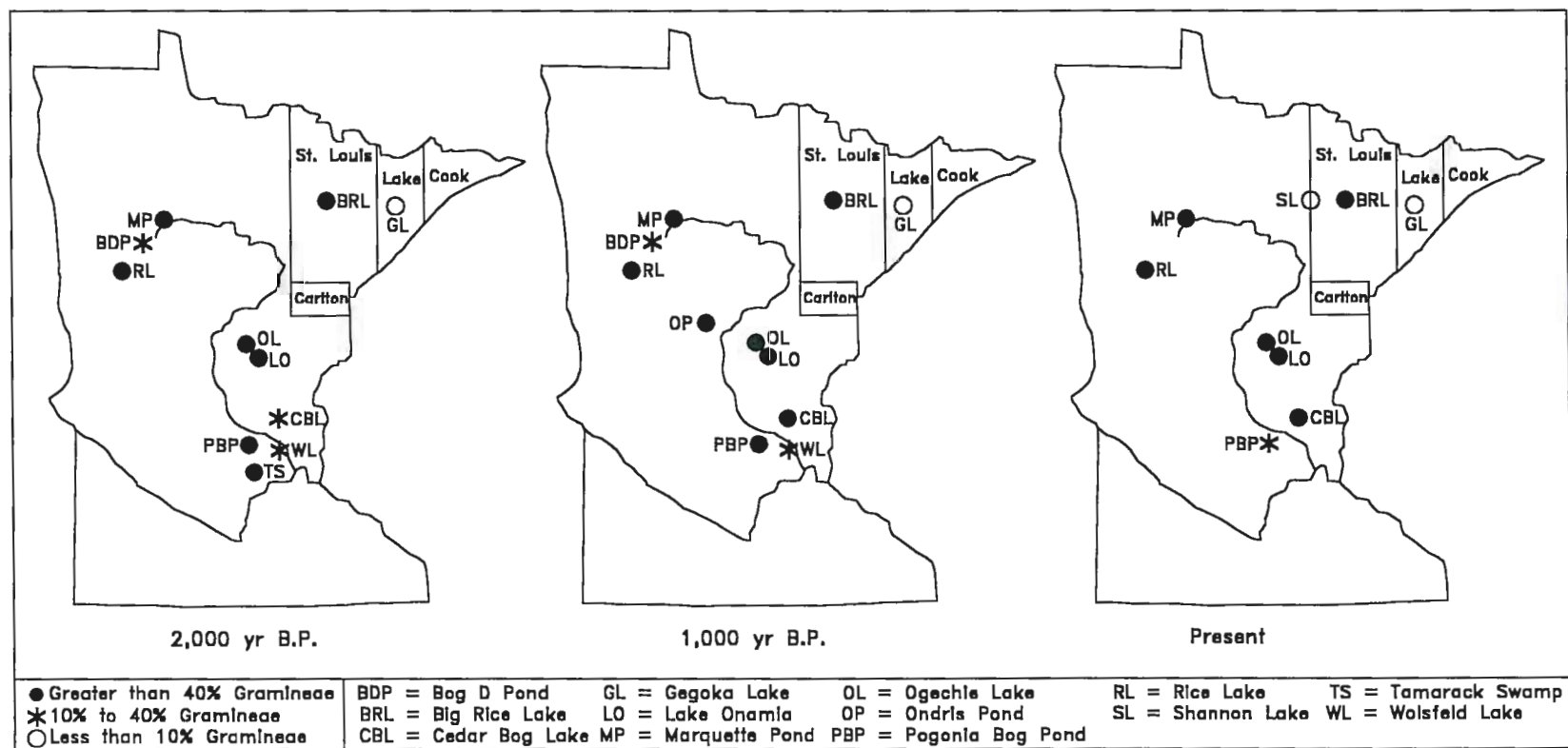


Figure 95. Location map of Gramineae rise pollen sites in Minnesota: 3,000 yr B.P.–Present.

Currently, there is not enough data available to determine to what extent wild rice was available to fully to begin to understand the distribution and extent of wild rice availability during the Paleoindian and Archaic periods. However, the palynological evidence does indicate that wild rice was potentially available in harvestable quantities prior to the Woodland Period for use by Native Americans.

There is a Paleoindian site at Big Rice Lake, and a Paleoindian and Archaic occupation at the Misiano site close to Gegoka Lake. Pollen data from both of these lakes indicate that wild rice was available during the Paleoindian and Archaic periods. Therefore, Paleoindian and Archaic would have had access to this food source.

According to G.R. Peters (personal communication, 2000), there is evidence for the manufacture of dugout canoes at the Misiano site, which has both Late Paleoindian and Early Archaic components. Several trihedral adzes were recovered that are interpreted by Peters to indicate woodworking. Archaic fire hearths were also found that contained no burnt bone or any other indications of their use as cooking fires. Disseminated charcoal fragments were found throughout the site sediments and deep in the site sediments. G.R. Peters (personal communication, 2000) believes that the lack of burnt bone and abundance of deeply buried and disseminated charcoal in conjunction with the trihedral adzes indicate the building of dugout canoes by burning and wood working. It is at this time, the beginning of the Archaic about 7,000 years ago, that white pine migrated into the area. There are historical records of white pine attaining the height of 75 m (250 ft) and having a diameter of 3 m (10 ft) or greater (Stensaas, 1996). The migration of the large

growing white pine into the area may have provided the first trees large enough for the manufacture of dugout canoes. The probable presence of canoes in the Archaic provides a means to easily gather wild rice.

Further studies specifically targeting lake deposits that could have supported large stands of wild rice between 10,000 and 4,000 years ago need to be undertaken in order to understand the expansion and abundance of wild rice in northeast Minnesota and its availability to the Native American inhabitants.

COULD WILD RICE HAVE BEEN UTILIZED WITHOUT LEAVING A SIGNATURE IN THE ARCHAEOLOGICAL RECORD?

At the Big Rice site, which is interpreted to be a large rice processing site (Peters and Motivans, 1984), over 50,000 sherds of Laurel, Blackduck, Sandy Lake, and Selkirk ceramics were recovered. This suggests that the pottery was instrumental in the processing of wild rice (Peters and Motivans, 1984).

Although there appears to be a relationship between the apparent increase in abundance of wild rice and the advent of pottery use during the late Holocene in northeast Minnesota, the evidence for this is scanty. In the study area, there are only three lakes that have archaeological sites that show good evidence for the gathering and processing of wild rice. Lake Jeannette directly north of Tower, Minnesota on the Echo Trail, Shannon Lake, and Big Rice Lake all have sites on that contain pottery and ricing jigs.

It is postulated by Gibbon and Caine (1980) that the transition from Middle to Late Woodland in eastern Minnesota involved several major shifts in subsistence emphasis. One of these is an increased dependence on wild rice as a major food source. Gibbon and Caine (1980) also suggest that one of the reasons for the transition may have been the availability of wild rice. However, the evidence presented here does not totally support this hypothesis. The pollen data does indicate an increase in the abundance of wild rice during the Woodland Period. The data also indicate that wild rice was probably available in harvestable quantities during the Archaic and Paleoindian periods as well.

If wild rice was available in harvestable quantities during the Archaic and Paleoindian periods as the Gramineae pollen data infer, what evidence could there be in the archaeological record indicating the use of wild rice, or could those early Native Americans have utilized wild rice without leaving a signature in the archaeological record? Is it possible to gather, process, and cook wild rice in such a way that no evidence of its use would be preserved for future archaeologists to find?

The most obvious evidence for the utilization of wild rice by Archaic and Paleoindian peoples would be direct evidence in the form of wild rice grains, however they may be very hard to find. McAndrews (1984) felt that carbonized wild rice grains do not preserve as well as other seeds because they are long and narrow with a relatively thin seed coat. Other than wild rice seeds, ricing jigs in unquestionable Paleoindian or Archaic context are the only other type of direct evidence that could leave a signature in the archaeological record that these aceramic peoples utilized wild rice. Does the absence of ricing jigs in Paleoindian or Archaic context imply that wild rice was not utilized by these people? It is also thought that Native Americans did not utilize dugout canoes in northeast Minnesota until the Archaic, does this mean the Paleoindian people had no way of gathering wild rice and therefore, did not use it even if wild rice was available? Ethnographic accounts and a recent interview with an Ojibwe elder indicate that wild rice can be gathered without the use of a canoe, processed without the use of pottery or ricing jigs, and cooked without the use of pottery.

Historically, in water too shallow for canoes, wild rice was sometimes tied in bundles for later harvesting. When the wild rice was mature, mats could be spread between the rows on the water. The grains could then be knocked onto the mats for collection (Jenks, 1900; Vennum, 1988). During dry years in water too shallow for canoes, the Ojibwe collected wild rice by walking in the lake and knocking the wild rice into a basket (J.H. McMillen, Ojibwe elder, personal communication, 2000). Either one of these methods could have been utilized for the gathering of wild rice and not leave a signature in the archaeological record.

Traditionally, after collection, the wild rice grains were parched or roasted to preserve it and to aid in the removal of the hulls. The wild rice was parched by heating it in a container over a fire and stirring it to keep it from burning (Jenks, 1900; Densmore, 1928; Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988). It is believed that the vast amounts of ceramics recovered from ricing sites were originally used to parch rice in (G.R. Peters, personal communication, 2000). However, according to Vennum (1988), wild rice could be parched by roasting it on hot, flat rocks, in pits lined with stones heated by a fire in the depression, or using tightly woven fire resistant scouring rush mats propped over a fire. Dore (1969) reports that a large basket or bowl was placed over an open fire to parch wild rice.

In lieu of parching, wild rice could also be dried and cured at the same time by placing it on a scaffold over a small fire (Jenks, 1900; Densmore, 1928; Vennum, 1988). Wild rice was also cured by sun drying alone without the aid of either smoke drying or parching (Jenks, 1900; Taube, 1951; and Saunders, 1976; J.H. McMillen,

personal communication, 2000). Wild rice can also be cured in a basket by adding hot rocks (J.H. McMillen personal communication, 2000).

Following curing, the chaff needed to be removed from the grain. This was done by digging a hole or ricing jig in the ground, lining it with some type of material, placing wild rice in the hole, and stomping it with the feet to remove the hulls (Jenks, 1900; Densmore, 1928; Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988). Hulls removed in this manner, does leave a signature in the archaeological record. However, there are several alternative to this method of hulling wild rice that will not leave a signature. Instead of digging a hole to make a ricing jig, a hollowed out stump could be used for a jig. J.H. McMillen (personal communication, 2000) relates the use of a stump that had been hollowed out by burning for a ricing jig and that stump was used for several years and could be transported from one processing site to another. Wild rice can be placed in a bag and beaten with a stick to remove the husks (Jenks, 1900; Taube, 1951), or rolled with a log like a rolling pin (Vennum, 1988). It has also been reported that hulling has been done by the wild rice being placed on a fresh (green) deerskin laid over coals, and then trodden by a boy (Jenks, 1900; Vennum, 1988). Wild rice can be laid on a skin and flailed to remove the husk or one can pound dried wild rice into a mass, place it into a container of water, and skim off the floating hulls from the wild rice which sinks (Jenks, 1900). The simplest way hulls can be removed from wild rice is by rubbing the grains between the fingers (Jenks, 1900; Taube, 1951)

If hulling was done in any manner in which the wild rice grains were not directly removed from the hulls, winnowing was done to remove the loosened chaff from the grain. Traditionally, winnowing is done by throwing the wild rice into the air from bark trays and letting the wind blow the chaff away while the grains fell onto a blanket (Jenks, 1900; Densmore, 1928; Moyle, 1944; Taube, 1951; Dore, 1969; Vennum, 1988).

Cooking of wild rice can be done in bark pails suspended above a fire (Vennum, 1988). According to ethnographic accounts, wild rice can also be eaten without processing (Vennum, 1988). Freshly harvested green wild rice can be cooked in as few as 10 minutes or even by simply pouring boiling water over it (Vennum, 1988; J.H. McMillen, personal communication, 2000).

Based on the ethnographic data summarized here, wild rice can be harvested, preserved, stored, and cooked without the use of ceramics or canoes. Therefore it is possible that wild rice could have been utilized by preceramic cultures without leaving any signature in the archaeological record.

Although many lines of indirect evidence supports the potential for the use of wild rice during the Archaic and possibly the Paleoindian, direct evidence is lacking. However, I find it hard to believe that early Native Americans would pass up such an excellent food source if available.

COMPARISON OF ARCHAEOLOGICAL SITE LOCATION IN RELATION TO HISTORICAL WILD RICE LAKES

A comparison of prehistoric archaeological sites was undertaken in order to assess if there is a greater association of Woodland sites with historical wild rice lakes than that of Paleoindian and Archaic sites. The hypothesis is that if intensive wild rice utilization is, for the most part, restricted to the Woodland Period, then a greater number of Woodland sites would be associated with wild rice lakes.

In northeast Minnesota, approximately 1,500 archaeological sites have been identified in the four county area. Of the 1,500 sites, only 280 have been associated with a cultural tradition. There are 148 of the sites identified as Woodland and 132 sites identified as Paleoindian/Archaic. Currently 219 modern wild rice sites have been identified in the study area.

Of the 132 sites identified as Paleoindian/Archaic, 12 are located on current wild rice lakes (Plate 10) or approximately 1%. Fifty-six of the 148 Woodland sites are located on current wild rice lakes (Plate 11) or approximately 38%. The data indicate that there is a much greater association of Woodland sites to historic wild rice lakes than that of the Paleoindian/Archaic sites.

However, the available data are greatly biased and probably does not accurately reflect settlement patterns for any of the archaeological periods. Most of the sites were identified as part of Cultural Resource Management investigations, and are consequently located near urban centers or roads. Some of the sites were identified by Superior National Forest personnel as a part of forest inventory and management, and are located in parcels of particular interest, especially timber sales.

Another bias is that a great many of the Paleoindian/Archaic sites have been located around the reservoir lakes near Duluth which is part of a hydroelectric system that require archaeological assessment in order to maintain their license. Because of this federal requirement, this area has been intensively surveyed. In addition, the reservoir lakes have also been intensively surveyed over the past 50 years by Elaine Redepenning, an amateur archaeologist who has recorded numerous sites in the area.

In addition to the sampling bias, the identification of most of the Woodland sites are based solely on the presence of ceramics. Therefore, many of the unidentified sites without ceramics may be Woodland sites. Furthermore, the function of most of the sites is unknown. This means that even though a Woodland site is located on a wild rice lake, it does not mean the inhabitants were there to gather rice. A vast majority of the archaeological sites located in the area, have been identified either by surface finds or shovel tests and identification is based on very few artifacts making it understandable why much of the information needed to make an accurate assessment of the relationship of archaeological sites to wild rice lakes is not currently available.

Many of the Paleoindian/Archaic sites that are not located on wild rice lakes, are located on non wild rice lake or reservoirs. Without knowing the history of each of these lakes, we do not know if some of these lakes supported wild rice during Paleoindian/Archaic occupation. This is especially true of the Paleoindian/Archaic sites located on the reservoir lakes system, the reservoirs have flooded the original

lakes and rivers and, at least, in the instance of Wild Rice Lake Reservoir, destroyed a large wild rice lake.

Although the data are biased, they do provide an indication that settlement and subsistence patterns were changing. The data also indicate that there is a greater affiliation of Woodland Sites with wild rice lakes than that of Paleoindian/Archaic sites suggesting that wild rice became a more important food resource in the Woodland Period. The preliminary study also indicates that more precise data, in terms of site function and cultural affiliation, is needed to make an accurate assessment of the relationship of Paleoindian/Archaic and Woodland peoples to wild rice lakes.

VII. CONCLUSIONS

Seven fundamental objectives were investigated in this thesis. 1) Based on palynological data, a paleoenvironmental reconstruction has been created that can serve as a context for component site sequences at the Big Rice, Cloquet Lake Boat Landing, Bearskin Point, and Misiano archaeological sites in the Arrowhead Region of northeast Minnesota. 2) A history of wild rice for northeast and greater Minnesota is provided based on existing and new pollen data. 3) What constitutes a wild rice lake past and present has been evaluated. 4) A means of determining the probable presence of wild rice in the paleoecological record of a lake based on pollen data is provided. 5) The potential for the use of wild rice as a food source prior to the Woodland Period in northeast Minnesota based on pollen data has been evaluated. 6) Based on historic and ethnographic data, it has been determined that it is possible to extensively use wild rice without leaving a signature in the archaeological record. 7) It has been determined, based on currently available data, that there is a weak correlation between Woodland archaeological sites and historical wild rice lakes.

Based on palynological evidence, during the time of Early Paleoindian presence in northeast Minnesota, tundra vegetation covered the area. At the beginning of the Late Paleoindian Period (10,500 yr B.P.) a shrub parkland or forest-tundra composed of dwarf birch, shrub willow, and juniper scattered with black and white spruce and tamarack prevailed. This vegetation was replaced by a conifer-hardwood forest by approximately 10,200 yr B.P. A transition to a mixed conifer-hardwood forest occurred about 9,000 yr B.P. as spruce declined. Coincident with

the end of the Late Paleoindian and the beginning of the Archaic white pine migrated into the area replacing jack/red pine at approximately 7,000 yr B.P. Spruce had returned to the area by 4,000 yr B.P. with the return of cooler and moister conditions. The current mixed conifer-hardwood forest was established by the beginning of the Woodland Period at about 2,500 B.P. A rise in ragweed pollen indicates Euro-American settlement and deforestation beginning about 1890.

Cycles of nutrient enrichment are indicated in Big Rice, Cloquet, Gegoka, and East Bearskin lakes based on nonsiliceous algae recovered in conjunction with pollen from lake sediment cores. Oscillations in nonsiliceous algae abundance probably result from changing environmental and/or limnologic conditions, as well as by competition from macrophytic vegetation. The changes in the nutrient status of the lake probably did not have a direct affect on Native American inhabitants, however, changes in lake trophic status may have affected the availability of aquatic resources.

The Gramineae pollen profiles of 10% to 40% and Gramineae pollen grain size distribution data, indicate that wild rice was present in harvestable quantities at various times in the last 10,000 years. Although the harvesting of wild rice is usually associated with the Woodland Period and the advent of ceramics, wild rice was available during previous archaeological periods. Based on the available pollen evidence, wild rice became more abundant during the Woodland Period. However, this evidence may be the result of site selection rather than the prehistoric abundance of wild rice. Most palynological studies in which a Gramineae rise is attributed to the expansion of wild rice were not undertaken to investigate wild rice but were

paleoecological investigations to reconstruct vegetational change in the area. Most sites that have been investigated specifically to understand the history of wild rice have been undertaken at lakes that currently support a large stand of wild rice. Many lakes in the past were probably capable of supporting harvestable quantities of wild rice. However, as sediment continued to infill these lakes, they became bogs and were no longer able to support wild rice indicating wild rice beds extant during the Paleoindian and Archaic periods may now be infilled.

Wild rice was probably present in the shallows in many wild rice lakes prior to its expansion over most of the lake. At Shannon Lake, wild rice is growing in large stands in the bays and shallows and the uppermost lake sediments have Gramineae pollen percentage values of less than 6%, indicating that wild rice may be present in quantities large enough to provide a major food source even though Gramineae pollen profiles are less than 40%. In lakes that apparently have never supported wild rice, Gramineae pollen profiles are usually less than 10%. Based on the Gramineae abundance and Gramineae pollen grain size distribution data from Shannon Lake, even lakes with less than 10% Gramineae pollen values may have appreciable stands of wild rice. In Gramineae pollen profiles from lakes with percentage values between 10% and 40%, wild rice may have been present in quantities large enough to provide a considerable subsistence component throughout the late Paleoindian and most of the Archaic Period.

The use of wild rice is usually associated with Woodland Tradition and the need for ceramics in processing wild rice. There is almost no direct evidence

supporting the use of wild rice in the aceramic Archaic Period and none from the Paleoindian period. However, ethnographic information suggests that wild rice could have been extensively utilized by early Native Americans by means that would not leave a signature in the archaeological record.

Based on pollen analysis, two complementing criteria can be used to identify wild rice lakes in the paleoecological record, Gramineae abundance data and Gramineae pollen grain size distribution data. Gramineae pollen grain size distribution data are especially useful in identifying the presence in wild rice lakes that have low to moderate Gramineae abundances. This usefulness of using both palynological methods to determine prehistoric wild rice lakes is demonstrated by the Wild Rice Lake Reservoir pollen sequence.

Currently, there is no limiting criteria to determine what constitutes a wild rice lake. It appears that the criteria for determining what constitutes a wild rice lake is dependant on the questions asked and how the data from the lake are to be used.

A preliminary comparison of Paleoindian/Archaic and Woodland site location and historic wild rice lakes indicates that there is a much greater association of Woodland sites to historic wild rice lakes than that of Paleoindian/Archaic sites.

Based on the evidence presented, our knowledge of the prehistoric history and use of wild rice is extremely limited. It is evident that a great many more investigations, both paleoecological and archaeological, need to be undertaken to provide a more complete understanding of the history of wild rice and its use by Native Americans in Minnesota.

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Appendix I: Historic Wild Rice Lakes Plotted on Plates 10 & 11

Map Number	Lake Name	County Name
1	Bang Lake	Carlton
2	Bob Lake	Carlton
3	Cedar Lake	Carlton
4	Cross Lake	Carlton
5	Dead Fish Lake	Carlton
6	Hardwood Lake	Carlton
7	Hay Lake	Carlton
8	Island Lake	Carlton
9	Jaskari Lake	Carlton
10	Kettle Lake	Carlton
11	Kettle Lake	Carlton
12	Miller Lake	Carlton
13	Moose Lake	Carlton
14	Perch Lake	Carlton
15	Rice Portage Lake	Carlton
16	Tamarack Lake	Carlton
17	Wild Rice Lake	Carlton
18	Anchor Lake	St. Louis
19	Artichoke Lake	St. Louis
20	Balkan Lake	St. Louis
21	Bear Lake	St. Louis
22	Beartrap Lake	St. Louis
23	Beaver Lake	St. Louis
24	Big Lake	St. Louis
25	Big Rice Lake	St. Louis
26	Big Rice Lake	St. Louis
27	Black Lake	St. Louis
28	Blueberry Lake	St. Louis
29	Bootleg Lake	St. Louis
30	Breda Lake	St. Louis
31	Bug Lake	St. Louis
32	Canary Lake	St. Louis
33	Caribou Lake	St. Louis
34	Comet Lake	St. Louis
35	Cranberry Lake	St. Louis
36	Crane Lake	St. Louis
37	Dollar Lake	St. Louis
38	Duck Lake	St. Louis
39	Echo Lake	St. Louis
40	Elliott Lake	St. Louis
41	Fivemile Lake	St. Louis

Map Number	Lake Name	County Name
42	Fourmile Lake	St. Louis
43	Gafvert Lake	St. Louis
44	Gansey Lake	St. Louis
45	Gill Lake	St. Louis
46	Grand Lake	St. Louis
47	Grass Lake	St. Louis
48	Grassy Bay	St. Louis
49	Grassy Lake	St. Louis
50	Grassy Lake	St. Louis
51	Grassy Lake Bay	St. Louis
52	Gull Lake	St. Louis
53	Hay Lake	St. Louis
54	Hay Lake	St. Louis
55	Hay Lake	St. Louis
56	Hay Lake	St. Louis
57	Hay Lake	St. Louis
58	Hay Lake	St. Louis
59	Hoodoo Lake	St. Louis
60	Horseshoe Lake	St. Louis
61	Johnson Lake	St. Louis
62	King Lake	St. Louis
63	Knuckey Lake	St. Louis
64	Kylen Lake	St. Louis
65	Lapond Lake	St. Louis
66	Leeman Lake	St. Louis
67	Lieuna Lake	St. Louis
68	Little Birch Lake	St. Louis
69	Little Mesaba Lake	St. Louis
70	Little Rice Lake	St. Louis
71	Little Sandy Lake	St. Louis
72	Long Lake	St. Louis
73	Low Lake	St. Louis
74	Lower Pauness Lake	St. Louis
75	Martin Lake	St. Louis
76	Moose Lake	St. Louis
77	Moose Lake	St. Louis
78	Mud Hen Lake	St. Louis
79	Mud Lake	St. Louis
80	Mud Lake	St. Louis
81	Mud Lake	St. Louis
82	Mud Lake	St. Louis
83	Mud Lake	St. Louis

Map Number	Lake Name	County Name
84	Mud Lake	St. Louis
85	Myrtle Lake	St. Louis
86	Nels Lake	St. Louis
87	Nichols Lake	St. Louis
88	One Pine Lake	St. Louis
89	Oriniack Lake	St. Louis
90	Papoose Lake	St. Louis
91	Pelican Lake	St. Louis
92	Perch Lake	St. Louis
93	Picket Lake	St. Louis
94	Prairie Lake	St. Louis
95	Rainy Lake	St. Louis
96	Rat Lake	St. Louis
97	Rat Lake	St. Louis
98	Rice Bay	St. Louis
99	Rice Lake	St. Louis
100	Rice Lake	St. Louis
101	Rice Lake	St. Louis
102	Round Lake	St. Louis
103	Ruth Lake	St. Louis
104	Sandy Lake	St. Louis
105	Seven Beaver Lake	St. Louis
106	Shannon Lake	St. Louis
107	Side Lake	St. Louis
108	Sixmile Lake	St. Louis
109	Stone Lake	St. Louis
110	Stone Lake	St. Louis
111	Stone Lake	St. Louis
112	Sturgeon Lake	St. Louis
113	Sunset Lake	St. Louis
114	Susan Lake	St. Louis
115	Turpela Lake	St. Louis
116	Twin Lakes	St. Louis
117	Twin Lakes	St. Louis
118	Twin Lakes	St. Louis
119	Unnamed Lake	St. Louis
120	Upper Pauness Lake	St. Louis
121	Vang Lake	St. Louis
122	Vermilion Lake	St. Louis
123	Wabuse Lake	St. Louis
124	Wagon Wheel Lake	St. Louis
125	Washusk Lake Number One	St. Louis

Map Number	Lake Name	County Name
126	White Iron Lake	St. Louis
127	Wild Rice Lake Reservoir	St. Louis
128	Wolf Lake	St. Louis
129	Bald Eagle Lake	Lake
130	Basswood Lake	Lake
131	Birch Lake	Lake
132	Bluebill Lake	Lake
133	Bonga Lake	Lake
134	Cabin Lake	Lake
135	Campers Lake	Lake
136	Charity Lake	Lake
137	Christianson Lake	Lake
138	Cougar Lake	Lake
139	Cramer Homestead Lake	Lake
140	Cramer Lake	Lake
141	Crooked Lake	Lake
142	Crown Lake	Lake
143	Dumbbell Lake	Lake
144	Dumbbell River Pool	Lake
145	Ella Hall Lake	Lake
146	Fall Lake	Lake
147	Fools Lake	Lake
148	Gabbro Lake	Lake
149	Garden Lake	Lake
150	Gegoka Lake	Lake
151	Greenwood Lake	Lake
152	Harris Lake	Lake
153	Hjalmer Lake	Lake
154	Hoist Lake	Lake
155	Hula Lake	Lake
156	Isabella Lake	Lake
157	Jack Lake	Lake
158	Kawishiwi Lake	Lake
159	Little Gabbro Lake	Lake
160	Little Wampus Lake	Lake
161	Lobo Lake	Lake
162	Manomin Lake	Lake
163	McDougal Lake	Lake
164	Moose Lake	Lake
165	Mud Lake	Lake
166	Mud Lake	Lake
167	Muskeg Lake	Lake

Map Number	Lake Name	County Name
168	Newton Lake	Lake
169	Newton Lake	Lake
170	Nine A M Lake	Lake
171	Papoose Lake	Lake
172	Perent	Lake
173	Railroad Lake	Lake
174	Rice Bay	Lake
175	Rice Lake	Lake
176	Roe Lake	Lake
177	Round Island Lake	Lake
178	Sand Lake	Lake
179	Scott Lake	Lake
180	Slate Lake	Lake
181	Snowbank Lake	Lake
182	Source Lake	Lake
183	Sourdough Lake	Lake
184	Stony Lake	Lake
185	Upland Lake	Lake
186	Vera Lake	Lake
187	Wampus Lake	Lake
188	Wind Lake	Lake
189	Wood Lake	Lake
190	Bigsby Lake	Cook
191	Caribou Lake	Cook
192	Caribou Lake	Cook
193	Christine Lake	Cook
194	Cuffs Lake	Cook
195	Elbow Lake	Cook
196	Fente Lake	Cook
197	Fourmile Lake	Cook
198	Grassy Lake	Cook
199	Gust Lake	Cook
200	Jack Lake	Cook
201	Kelly Lake	Cook
202	Marsh Lake	Cook
203	Moore Lake	Cook
204	North Fowl Lake	Cook
205	Northern Light Lake	Cook
206	Peterson Lake	Cook
207	Phoebe Lake	Cook
208	Prout Lake	Cook
209	Rib Lake	Cook

Map Number	Lake Name	County Name
210	Rice Lake	Cook
211	Richey Lake	Cook
212	South Fowl Lake	Cook
213	Teal Lake	Cook
214	Toohey Lake	Cook
215	Unnamed Lake	Cook
216	Unnamed Lake	Cook
217	Unnamed Lake	Cook
218	Unnamed Lake	Cook
219	White Pine Lake	Cook